

AN
E P I T O M E
OF
NATURAL and EXPERIMENTAL
PHILOSOPHY,
INCLUDING
GEOGRAPHY, with the Use of the GLOBES,
AND OF AN
IMPROVED ANALEMMA,

By which may be solved the common Problems
of the CELESTIAL GLOBE.

DESIGNED FOR THE USE OF SCHOOLS.

The Whole, being a proper MEMORIAL-BOOK, for Young
Ladies or Gentlemen, who attend public Courses; more par-
ticularly those of the Author.

*Nature and Nature's Laws lay hid in Night,
GOD said, let Newton be, and all was Light.*

By BENJAMIN DONN,
MASTER OF THE MATHEMATICAL ACADEMY,
AT BRISTOL.

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P R E F A C E.

HAVING been desir'd by some of my Auditors to print my PHILOSOPHICAL LECTURES, I have drawn up this Epitome, in some Degree to comply with their Request; not thinking it adviseable, as yet, to publish the Lectures at large: Because, as Time will permit, I hope to render them more extensive and complete; and give them to the World in my intended Course of Mathematical Learning; of which two Volumes are already published, and others preparing for the Press.

It is frequently observ'd that those fleeting Ideas which young LADIES and GENTLEMEN acquire by attending a public COURSE OF LECTURES, soon vanish for want of a proper MEMORIAL-BOOK, to which they may have recourse, to refresh their Memories and fix them in their Minds.

IN this Epitome the necessary Terms are defined, and the principal Propositions given, whose Truths are shewn, in A COURSE OF EXPERIMENTAL PHILOSOPHY, GEOGRAPHY, AND ASTRONOMY. Whereby any one with only common Sense, and a moderate Degree of Attention, although unskilled in the Mathematical Sciences, may readily understand the principal Phænomena of Nature, which have been discovered by the most learned Philosophers in several Ages: And Mathematicians themselves, be agreeably entertained,

ed, by seeing those Propositions, which have been demonstrated by a Chain of Reasoning, illustrated and proved by Experiments, on a proper Apparatus. By

Mathematical-Academy,
Bristol, July 1, 1769.

B. DONN.

DIRECTIONS to the BINDER.

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This Epitome is entered in the Hall-Book
of the Company of Stationers.

ON THE
USEFULNESS
OF
NATURAL PHILOSOPHY:

A
P O E M.

O THOU! Enthron'd above the starry Orbs,
Great Cause of Causes! Everlasting GOD!
Assist a grov'ling Worm, who feebly tries
To sing thy mighty Works in grateful Verses:
O, let a Spark of that celestial Fire,
Which touch'd ISAIAH's Lips, influence mine!

While Chaos reign'd, and Darkness cloth'd the Deep,
Th' ætherial Spirit hover'd o'er its Mass.
Hark! From the Slumbers of Eternity,
Forth from the great ETERNAL's bright Abode,
Let there be Light! The sacred FIAT rung,
And all around Light instantaneous rose!
With equal Might, in six successive Days,
The Sov'reign ARCHITECT his Work perform'd,
The Seventh beheld the new Creation smile;
Then rested GOD from all his glorious Work.
High in the Vault of Heav'n, the central Sun
Superior thone, in radiant Lustre dress'd,
With native Heat to great Degree endow'd,
And smil'd on frozen Saturn's distant Ring:

Himself a World, amidst surrounding Worlds !
 About him, all the planetary Train
 Joyful, began their new harmonious Dance.
 In stated Periods next the *Cemets* mov'd,
 Large, solid Bodies, with a Length of Tail;
 Elliptical, and various in their Course,
 Still more, or less attracted by his Heat.
Earth on her Center mov'd from West to East,
 The *Third* amidst the wond'rous *System* plac'd;
 In all her gayest Drapery adorn'd,
 To strike the Eye, and captivate each Sense;
 And round her mov'd the *Moon's* officious Light,
 Birds, thro' extensive Fields of liquid Air,
 By quick Transition, sported on the Wing,
 And sung in various Notes their *Maker's* Praise.
 The Streams prolific pour'd the finny Race,
 While mighty *Ocean* with new Monsters teem'd;
 The *Whale*, with Bulk enormous to behold,
Bebemoth, and the great *Leviathan*,
 With ev'ry Species of the rolling Deep.
 Beasts of a thousand Kinds then trod the Plain,
 Reptiles and Insects shone in gay Attire,
 Ting'd with unnumber'd glossy Dyes, that prov'd
 Shade above Shade, the *Painter's* matchless Art.
Man then was form'd, as sov'reign Lord of All,
 More fair and wise than all the brutal Train,
 With Soul divine endow'd, stupendous Frame,
 Godlike, erect, with *Reason* for his Guide;
Reason, the Gift of great indulgent Heav'n !
 This dignifies the *Man* beyond the *Brute*;
 This bids him hold sweet Converse with the Skies !
 He, with his Talents, and superior Sense,
 Thro' *Nature* takes a philosophic View,
 While Wonders, rais'd on Wonders, strike his Eyes !
 If yon vast Vault demand his earnest Search,
 There Symmetry, magnificently great,

Form'd by unerring Wisdom stands confess'd;
Where Worlds on Worlds in ample Order shine,
Thro' all the boundless Tracks of Universe.

Two Principles endow the Soul of Man,
His *Understanding*, and his better *Will*;
That, thro' a Thirst of Knowledge he perfects,
This, by his Goodness, more enobled shines;
Nothing below can more enlarge the first,
Or raise the last, than studying *Nature's* Rules;
Rules, which observ'd, will lead to *Nature's* God.

O Man! His much-belov'd, his darling Care,
Ne'er let the Gifts He plenteous pours around
For thy Delight and Use, be pour'd in vain:
Let ev'ry Morn thy Gratitude ascend!

Would'st thou be rich?----Laborious dig thy Gold,
Dig Truth, dig Wisdom from the latent Mine;
Then coin, and use them for thy proper Use:
If ought to spare, bestow on human Kind,
And kindly shew them how to search for more.
This shall advance thee o'er the vulgar Crowd,
And claim Respect among the Sons of Men.

All hail PHILOSOPHY! Celestial Fair!
Sent from above, replete with ev'ry Good,
T' improve each striving Faculty within,
To mend our Morals, and refine the Heart.
Without thee, what were those resplendent Orbs,
With all the grand Appendage of the Skies?
'Those Stars, that twinkle in the vast Expanse,
From thy Assistance more conspicuous shine;
Silent they teach a Lesson to Mankind,
And light us on to Scenes of future Joy.
For Fruits of Knowledge, oft th' enraptur'd Mind
From Field to Field of Contemplation roves;
And forms from close Pursuits more gen'ral Laws,
Laws, which the great *Phænomena* explain
Of Earth, Sea, Air, and Regions far above.

She cancels Limits---glowing now ascends
 From Scale to Scale of Beings, 'till she soars
 In Thought profound, beyond Creation's Bounds,
 " To the first good, first perfect, and first fair."
 From Stage to Stage, now gradual she descends,
 Beneath ambrosial Dews, the Gift of Heav'n!
 Beneath the loud Applause of Angel-Hosts,
 And lights again on this terrestrial Sphere.

Whether this spacious Earth we traverse o'er,
 Or rove in Thought from *Indus* to the *Pole*;
 Whether we mount contemplative the Skies,
 And journey thro' Plurality of Worlds;
 Which Way so'er our darling Genius leads,
 We view the Footsteps of the *DEITY*!
 What rigid *Sceptic* boldly shall deny
Philosophy's of gen'ral Use to *Man*,
 When by its Study, he more clearly knows
 The Wisdom, Pow'r, and Attributes of *GOD*?
 The Mists of Error puzzle Men no more,
 Such as prevail'd, when dawn'd the mystic Art;
 Experience long all Darkness has remov'd,
 And Truth breaks round us with resistless Blaze---

Shall We, the noblest of Creation's Works,
 From Year to Year supinely spend our Time,
 Nor once indulge a scrutinizing Thought,
 How *Nature*, pregnant with all Life can crave,
 Preserves, throughout, one great, harmonious Round?
 To search her Ways will more Contentment yield,
 More lasting Pleasures, more exalted Joys,
 Than all the Stores the great *Peru* can give,
 Or precious Diamonds from *Golconda's* Mine.

Thro' Life's short Course, what trifling Toys amuse?
 Fraught with no bless'd Advantage to the Mind;
 Tho' ever studious to enhance Delight,
 And ev'ry Day Diversion shifts the Scene:
 Each Novelty grows languid in our Eyes,

While full Fruition palls upon the Sense;
 Beauties there are, which more refin'd can please,
 Which in more delicate Succession rise
 From *Wisdom's* chaste Embrace, and stricter Rules;
 Such as attend us thro' this dreary Vale,
 Nor leave us, 'till we leave terrestrial Things.

In Youth they firmly fix our wand'ring Thoughts;
 And stamp the best Ideas on the Mind;
 Add Lustre to the Paths of middle Life;
 Glow in the Bosom of the hoary Sage,
 Crown with illustrious Worth his rev'rend Head,
 And make him smile serene at Death's Approach.

Thro' various States Prosperity adorn
 Retreat and Comfort bounteously bestow,
 When stern Adversity tremendous frowns.
 Delight at Home, nor e'er disgust Abroad;
 They travel with us to remotest Climes,
 Make ev'ry Country yield a Tide of Joy;
 Attend thro' ev'ry Office of the Day,
 And when the Night returns, with us repose.

Innumerable Uses flow to Man,
 Thro' ev'ry Branch of circulating Trade,
 From the just Lights which *Nature's* Plan affords.
 With arduous Toil th' *Astronomer* acquires
 The Frame of Heav'n, made easy to his Sight;
 He views the vig'rous *Sun's* meridian Blaze,
 The *Moon*, and ev'ry *Star* that gilds the *Pole*,
 From hence, the *Merchant*, emulous of Wealth,
 At proper Periods, trusts the raging Seas;
 Knows when the Winds will gently swell the Sails,
 When blust'ring *Boreas* sleeps within his Cave,
 And either *India's* Stores become his own.
 The grave *Physician*, by close Study, finds
 The healing Virtues and Effects of Plants,
 With all the Tribes of medicable Herbs.
 With equal Care, the *Chymist* too attains

The Use of Metals, Min'rals, and their Stores,
 Prepares, dissolves, and analyses All.
 Th' Apothecary happily explores
 The various *Simples* of the fertile Field,
 And calls, by nicest Rules, his Antidote,
 To form his Med'cines, and restore Mankind.
 The poor *Mechanic*, with Attention due,
 His Myst'ries may enlarge, and gain Applause,
 And with Applause, perhaps attractive Gold.
 Led by her Laws, the *Husbandman* may learn,
 At proper Times, to fertilize his Lands,
 And make his Acres yield an hundred-fold,
 A golden Crop, from *Ceres*' lib'ral Hand.
 In short, look round this habitable Globe,
 View *Kings* and *Princes* more illustrious shine,
 Charm'd with the *Virtues* of *Philosophy*!
 From Stations high, by just Degrees, descend,
 Thro' ev'ry State subordinate to Life,
 What Man of Reason but adores the *Maid*?
 For Reason still attends her ev'ry Hour,
 Thro' ev'ry Region where she takes her Flight,
 Soars when she soars, and with Devotion glows.

PHILOSOPHY! Sure Guide to limpid Truth,
 Choice of the *Wise*, a Mystery to *Fools*,
 Who blind with Ign'rance, scorn thy winning Smiles.
 In Ages past, thou rear'dst thine honour'd Head,
 A while imperfect known---till rolling on
 With small Improvement down the Stream of Time,
 Thy Features more refin'd, and lovely grew:
 Finish'd at length by *Newton*'s plastic Hand,
Philosophy commenc'd a finish'd *Fair*,
 Adorn'd with ev'ry Beauty, Grace, and Charm,
 To win obedient Hearts, and gain Applause.
 O, more and more extend thy gentle Sway
 O'er *Virtue*'s favour'd Race, and bless Mankind!
 Make ev'ry *Fair* who crowns *Britannia*'s Isle

Enamour'd with thy Charms, still fairer grow
 O, raise an Emulation, truly great,
 In ev'ry Art each other to transcend !
 On either *Sex* kind *Nature* has bestow'd
 A just Proportion of indulgent Parts,
 And form'd alike Competitors for Praise :
 From Education only, Men are found,
 By Custom taught, to claim superior Sense :
 Rise, zealous rise, assert your native Rights,
 Thro' *Nature's* Volume diligently pry,
 And claim with us an equal Share of Fame.

What great, what glorious Properties has *Light* !
 Bless'd Emanation of th' *Almighty Pow'r* !
 The first material Link in Beings Chain !
 Worthy the *Fiat*, that first call'd thee forth
 From Darkness, and Confusion's wide Domain !
 Attracted by thy Pow'r, the ravish'd Eye
 Descants on all around with vast Delight ;
 The Soul exults amid her wond'rous Frame,
 For *Man's* the wond'rous Workmanship of God !
 Auspicious *Light* ! be friendly to Mankind ;
 Long o'er the Products of this fertile Globe
 Display thy Charms, 'till Time shall be no more.
 What various Dyes on Trees, Herbs, Fruits, and Flow'rs,
 Thy Rays refracted, beauteous pour abroad !
Light to the Peach imparts the Blush it wears,
 Tinges the Nest'rine with a deeper Red,
 Beams on the Plumb that soft, inviting Blue,
 And o'er *Pomona's* Gifts pours countless Charms :
 Paints ev'ry Colour in the *Peacock's* Tail,
 With splendid *Iris*, that celestial Bow.

How pow'rful proves the *Air's* elastic Force !
 As on the Pump Experiments confess :
 Creation's Fruits no more could vig'rous thrive,
 Than Man subsist without the fragrant Balm.
 Porous are all the vegetable Tribes,

And all receive fresh Draughts of vital Air,
 By just Gradation to the royal Oak,
 Or Cedar, which adorns the Mountain's Brow,
 Our Atmosphere all pond'rous presses round
 In strict Proportion o'er the Face of Things,
 Yet all sustain the vast, surprising Weight,
 Buoy'd by Resistance of internal Air.

The Winds from Vapours purge th' aërial Climes,
 Which, otherwise, would taint both Man and Beast.
 What Care has that *Almighty Mind* bestow'd
 On these, his lower Works, Works all Divine!
 How worthy our Inspection and Regard!
 Let Pride abash'd sink humbly to the Dust,
 When we behold the same transcendent Skill
 At large display'd thro' *Nature's* ample Field,
 As in this glorious, fair Machine of *Man*.

Sing next, my *Muse*, what Uses flow from *Sound*,
 Whose Medium is the wide circumfluous Air;
 Caus'd by some sudden Stroke, the quav'ring Parts
 Affect the Tympanum, and strike our Ears.
 How soft, how pleasing to th' attentive Mind
 Are Notes, arising from melodious Strings!
 Artful they sooth our Troubles into Rest,
 And waft the Soul beyond her native Sphere.
 So *David* pleas'd the royal Ear of *Saul*,
 Banish'd all Discontent, all anxious Thoughts,
 And power'ful made the *Snakes* of *Envy* sleep.
Tarantula in vain envenom'd bite,
 If *Musick's* sov'reign Antidote oppose:
 By just Degrees, th' afflicted Patient feels
 No more a Numbness of his nat'ral Parts,
 Enliv'ning *Airs* affect his whole Machine,
 His Legs, Arms, Fingers, catch the thrilling Sound,
 With Joy he bounds, to perfect Health restor'd.
 From *Concords*, such great Benefits arise,
 And such the *Goodness* of the great Supreme!

What Pow'r has *Gravity* ! What mighty Force !
 By which all Bodies to their Center tend ;
 The *Sun* attracts the *Planets* in their Orbs,
 This Globe pale *Cynthia* gliding in her Sphere :
 All teeming Matter gravitates to Earth,
 Towards her Bowels, where her Center lies :
 On ev'ry Form it acts with equal Force,
 As much on Feathers as more pond'rous Gold !
 What Qualities the useful *Magnet* yields,
 Which constant points the Needle to the Pole,
 Unless betray'd by subterranean Ore !
 Without the *Loadstone's* necessary Aid,
 The *Mariner* in vain would plow the Deep,
 In Quest of foreign Ports, in foreign Lands.
 How great the Pow'r, the Wisdom, and Design,
 Of *One* almighty, all-creating God !
 Who form'd this World so useful and so fair,
 And from her Entrails gives such precious Gifts.

What various Scenes all wonderful arise
 From the Pursuit of *Electricity* !
 An Art well worthy of the greatest Praise ;
 Improv'd by Moderns thro' a Length of Years.
 Like some fair *Science* now she lifts her Head,
 And claims a Volume to record her Use.
 Great Truths have lately been disclos'd to Light,
 While undiscover'd lie ten Thousand more,
 Which Time and Study beauteous may unfold,
 And publish wide their Virtues to Mankind.

On Themes like these the *Muse* could much enlarge,
 T' enforce the Study of great *Nature's* Laws,
 And prove its Uses to the human Race ;
 But Time contracts her Song, and damps her Flight :
 A Chain of Subjects must remain unsung,
 Fraught equal with the great *Creator's* Pow'r.
 Here, let some Fav'rite of th' *Aionian Maids*

Assume the Theme, with Zeal divine impell'd
 While I, inspir'd with Gratitude and Love,
 With this Address conclude the sacred Song.
 Creation's *Lord!* Great *Nature's* glorious Guide!
 Who ever wakeful, from thy blest'd Abode,
 With piercing Eyes survey'st each dawning Thought,
 E're brought to Speech, and flowing from our Lips :
 Attend thine Ear a-while to suppliant Dust,
 Dust form'd by *Thee*, and form'd indeed divine !
 When Inclination prompts with warm Desires
 To search this Fabric of the lower World,
 Direct, auspicious *Guide*, our Search aright !
 Or when we strive to search the Heights above,
 Curious to trace thy more surprising Works,
Thou light us on to those celestial Scenes,
 Where Beauty, Order, Harmony conspire
 To raise Devotion, and exalt our Love !
 While *second Causes* studious we assign,
 Ne'er let us, mighty *Lord*, forget the *First!*
Thee, First and Last! by whom all Things were made,
 For thy own Glory, and the gen'ral Good. —
 What daring *Man* shall impiously attempt
 To set at naught thy great important Laws ?
 Nothing in vain has thy great Hand design'd,
 Replete with all that lavish Hearts can wish.
 Shall *Atheists* say this glorious Fabric rose
 From *Nature* only, not from *Nature's* GOD ?
 O reign *Supreme*, in Majesty ador'd,
 Extend thy Sceptre o'er the Hearts of Men ;
 Crush *Atheism* in its Birth ; from Age to Age,
 While *Thou* remain'st *One universal Cause*,
 The *Father*, and the *Sov'reign* of the World.

M A R C U S.

A N
E P I T O M E
O F
NATURAL and EXPERIMENTAL
PHILOSOPHY, &c.

LECTURE I.

In which by Way of Introduction, some of the most valuable Propositions in GEOMETRY, and the rationale of common MENSURATION will be mechanically proved—Sir Isaac Newton's Rules for Philosophizing—The Divisibility of Matter; and Laws of Motion—Composition and Resolution of Forces—Flying and Swimming accounted for.



It is absolutely necessary that every Person who would study GEOGRAPHY, ASTRONOMY, &c. should know something of Geometry.

In order to which we shall observe,

1st. That a *Physical Point* is an indefinitely small Quantity, as a Dot made with a fine Pen, or Point of the Compasses, as (.)

But a *Mathematical Point* is not a Quantity, being only a Term or Bound of a Quantity. Or in Euclid's

clid's Words, a Point is that which hath no Parts, or which hath no Magnitude.

2. A *Line* may be conceived to be generated by the Motion of a Point: If the Point in Motion moves continually in the same Direction, it then describes a Right Line, or is the nearest Distance between its two extreme Points.

as

But if the Point in Motion is continually changing its Direction, it is then a curvilinear Line, as Fig. 1. Plate I.

3. A *Plane Surface* or *Superficies* is that which has only Length and Breadth, and may be conceived to be generated by the Motion of a Line, as Fig. 2. Plate I.

4. A *Solid* is that which has Length, Breadth, and Thickness, and may be conceived to be generated by the Motion of a Surface, as, Fig. 3. Plate I. generated by the Plane A, moving on to B, and from thence to C.

5. An *Angle* is the Inclination of two Lines; and if the Lines are right, that is strait Lines, the Angle is called a right Lined Angle, as Fig. 4, 5, and 6. Plate I.

For the future, when we only say *Line*, we would be understood to mean Right Line.

6. If a Right Line stands upright on another Line, it is said to be perpendicular to that other Line, and the Angle so formed, is called a right Angle, as Fig. 5. Plate I.

7. An

7. An Angle which opens more than a Right Angle is called *obtuse*, as Fig. 6. Plate I. And an Angle which is less than a Right Angle, is call'd *Acute*; as Fig. 4. Plate I.

8. A Circle may be conceived to be formed by the turning round of a Pair of Compasses; as in Fig. 7. Plate I.

The Boundary Line of it is called the *Periphery* or *Circumference*, as A B D E A. A Right Line drawn through the Center C, and terminated on both Sides by the Circumference, as A D or B E is called the *Diameter*, and the Extent of the Compasses in describing it, or half the Diameter is called the *Radius*.

9. A Triangle is a Figure bounded by three Lines, as Fig. 8. Plate I.

10. A Square, is a four sided Figure; whose Sides are all equal, and Angles all right Angles; as Fig. 9. Plate I.

11. An Oblong, Rectangle, or Right angled Parallelogram, is that four sided Figure, which has all its Angles Right Angles, and opposite Sides equal; but not all its Sides equal to each other, as Fig. 2. Plate I.

12. Parallel Lines, are such as keep always at the same Distance from each other; as in Fig. 10. Plate I. B F being equal to C G, the Lines A D and E H are Parallel to each other.

13. Scholium. Mathematicians for the more easy comparing the Proportion which Angles bear

to each other, suppose the Circumference or Periphery of every Circle to be divided into 360 equal Parts, called *Degrees*, (so that 180 Degrees are a Semicircle or two Right Angles: And 90 Degrees a Quadrant or Right Angle) each of these Degrees for exact Computations, are supposed to be divided into 60 equal Parts, called *Minutes*, and each of these into 60 equal Parts called *Seconds*.

In Writing, the Character for Degrees is, °; Minutes, ' ; Seconds, ".——Example. Three Degrees Ten Minutes and Eighteen Seconds is compendiously expressed thus $3^{\circ} 10' 18''$.

GEOMETRICAL THEOREMS.

14. Theorem 1st. If two Lines intersect each other, the opposite Angles are equal. Thus, in Fig. 11. Plate I. The Angle A C E is equal to Angle B C D, and the Angle A C B is equal to the Angle E C D.

15. Theorem 2d. The Area of a Rectangle Parallelogram is equal to the Length multiplied by the Breadth. Thus, if a Plank represented in Fig. 2. Plate I. be 12 Feet long, and 2 Feet broad, it contains 12 multiplied by 2 equal to 24 square Feet, or in other Words, its Area is 24 Feet.

16. Theorem 3d. If a Triangle and Rectangle Parallelogram have equal Bases and Altitudes, (Heights) the Triangle is Half the Rectangle. Hence the Method of measuring or finding the Areas of Triangles is evident.

17. The-

17. Theorem 4th. In any Right angled Triangle, the Squares on the two shorter Sides, are equal to the Square on the longest Side.

Thus, in Fig. 12. Plate I. The Squares B and C taken together are equal to the Square A.

18. Theorem 5th. Equiangular Triangles are similar. That is, in Fig. 13. Plate I. If the Angle A is equal to the Angle D, the Angle B equal to the Angle E, and the Angle C equal to the Angle F. Then as AB is to DE so is AC to DF; and so is BC to FE.

19. Theorem 6th. The Area of any * Regular Polygon is equal to half the Perimeter multiplied by the Perpendicular let fall from the Center, to the Middle of one of the Sides. Thus in Fig. 14. Plate I. The Area of the Polygon is equal to half the Circumference ABCDEFA multiplied by HG.

20. Theorem 7th. The Area of a Circle is equal to half the Perimeter multiplied by half the Diameter.

21. Theorem 8th. Similar Figures are in Proportion to each other as the Squares of their like Sides. Thus, in two Squares, the Side of one being equal to twice the Side of the other, their Areas will be, as 2 multiplied by 2, to 1 multiplied by 1, that is, as 4 to 1.

of

* A Regular Polygon is a Figure whose Sides and their contained Angles are all equal to each other.

Of SOLID GEOMETRY.

22. Definition. As a Plane or Superficies has only Length and Breadth, a *Solid* has Length, Breadth, and Thickness.

23. Def. A *Cube* is a Solid bounded by six equal Squares; as Fig. 15. Pl. I.

24. Theorem 1st. A Cube is measured by multiplying the Length by the Breadth, and that Product by the Depth or Thickness; (which is called cubing the Side.)

25. Def. A *Parallelopipedon* is a Solid represented in Fig. 3. Pl. I. which is conceived to be generated by the Motion of a Rectangle Parallelogram, or Square A.

26. Theorem 2d. A *Parallelopipedon* is measured by multiplying the Length, Breadth, and Depth together.

27. Scholium. If the Base (or End) is a regular right-lined Figure, as a Square or Triangle, the Solid is called a *Prism*, and is measured by multiplying the Area of its Base by the Length. See Fig. 16 and 17. Pl. I.

28. Def. A *Pyramid* is a Solid whose Base is any right-lined Figure, and whose Sides are Triangles, whose Vertexes all meet in one Point, called the Vertex of the Pyramid.

29. Theorem 3d. A Pyramid is a third Part of its circumscribing Prism. Thus in Fig. 18 Pl. I. the Pyramid A C E is exactly one third of its circumscribing

scribing Prism B A F E C, and therefore its Content is equal to the Area of the Base D multiplied by a third of its Altitude A D.

30. Def. A *Cylinder* may be conceived to be generated by the Revolution of a Rectangle Parallelogram about one of its Sides; being in Form like a rolling Stone of a Garden.

31. Theorem 4th. The Content of a Cylinder is equal to the Area of its circular Base multiplied by its Length.

32. Def. A *Cone* is a Solid generated by the Revolution of a right-angled Triangle, about its Perpendicular. Thus, in Fig. 19. Pl. I. if the Triangle A D F be conceived to revolve on the Line F D, it will describe the Cone A D B.

33. Theorem 5th. A Cone is a Third of its circumscribing Cylinder. Thus in Fig. 19. Pl. I. the Cone A D B is a Third of its circumscribing Cylinder A E C B.

34. Theorem 6. A Sphere, Globe, or round Ball, is two Thirds of its circumscribing Cylinder. Thus in Fig 20. Pl. I. the Globe E is $\frac{2}{3}$ of the circumscribing Cylinder A B C D.

35. Theorem 7th. Similar Solids are in Proportion to each other, as the Cubes of their like Sides.

Thus two Cubes, the Side of one being equal to twice the Side of the other; the greater contains the lesser 8 Times. But 1 multiplied by 1 multiplied by 1, equal to 1, is the Cube of 1; and 2 multiplied by

by 2 multiplied by 2, equal to 8, is the Cube of 2; therefore they are as in the Theorem.

PHILOSOPHICAL LECTURES.

36. Having explained some preparatory Propositions of Geometry, we come now to our principal Design, to discourse on *Physics*, or *Natural Philosophy*; that is, the Science which leads us to the Knowledge of the principal Phænomena of Bodies, and the Laws by which *Nature*, or rather the God of *Nature* governs the Material World.

37. We cannot begin our *Philosophical Lectures* better, than by giving the Rules which Sir *Isaac Newton* has laid down, as the most certain Guide in these Enquiries, viz.

Rule 1. We are to admit of no more Causes of natural Things, than such as are both true and sufficient to explain their Appearances.

For what is more agreeable to Divine Wisdom, than to suppose it does nothing in vain?

38. Rule 2. Therefore, to the same natural Effects, we must as far as possible assign the same Causes. As of Respiration in a Man and in a Beast—the Descent of Stones in Europe and in America, &c.

39. Rule 3. The Qualities of Bodies which cannot be increased or diminished, and which are found to belong to all Bodies within the Reach of

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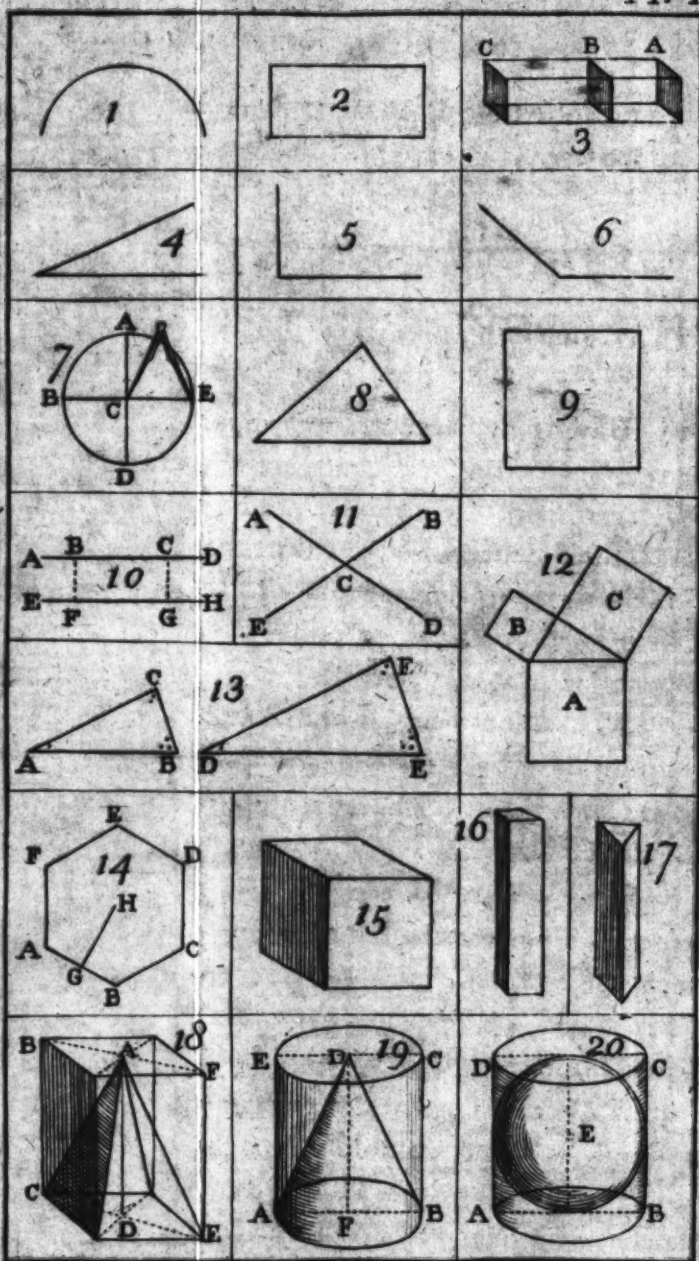
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our Experiments, are to be esteemed the universal Qualities of all Bodies whatsoever. Thus, because Extension, Divisibility, Impenetrability, Mobility, and Gravity, are found in all Bodies on which we make Experiments, we conclude they are Properties belonging to all Bodies whatsoever.

40. Rule 4. In Experimental Philosophy, we are to look upon Propositions collected by general Induction from Phænomena, as accurately or very nearly true; notwithstanding any contrary Hypothesis that may be imagined, 'till such Times as other Phænomena occur, by which they may be either rendered more accurate, or liable to Exception.

This Rule must be followed, that the Argument of Induction may not be destroyed by Hypothesis.

41. By *Matter* we understand whatever has Extension and Resistance.

42. Concerning the *Divisibility of Matter* many Disputes have arisen. Some contending that it is infinitely divisible, others denying it.

It is plain no Part of Matter can be assumed but the Mind can conceive it to be divided into a less Quantity, as a Half, Quarter, &c. Of this Division a Half, Quarter, &c. *ad infinitum*. But whether Nature does admit of Matter being capable of an actual Division, *ad infinitum* is not so easy to determine: And indeed the most probable Opinion is, that all Bodies are composed of a Collection of very minute Particles of Matter, not actually divisible. However, Nature proceeds in the actual Divisibility of Bodies in many Instances, into Particles

ticles so surprizingly subtle, as to be even beyond Human Comprehension.

We shall mention a few :

43. First. Dr. *Muschenbroek* says, that there was at Augsburg an Artist, who of *one Grain* of Gold drew a Thread 500 Feet long; which might have been actually divided into 360 Thousand Parts; for an Inch, as he observes, may be divided into 600 visible Parts, each of which will be as long as the Breadth of a fine Human Hair.

44. Second. That celebrated Philosopher Mr. *Boyle*, dissolved one Grain of Copper in Spirits of *Sal. Ammoniac*, which Solution being infused into 28534 Grains (or 4lb. 11oz. 8dwts. 22gr.) of Water, made it throughout of a Blue Colour. Now Water of the Weight of a Grain is the 37 ten thousandth Part of a Cubic Inch, and therefore the tinged Water was $105\frac{57}{100}$ Cubic Inches. But in every visible Part of the Water there was some Part of the Solution of Copper; and since in a Cubic Inch there are 216 Millions Parts visible to the Eye, one Grain of Copper will be divided at least into 22 Thousand 788 Millions of visible Parts. *This we illustrate by an Experiment nearly the same.*

45. Third. A Grain of Carmine divided into 921 Thousand 600 visible Parts. *Shewn by Exp.*

46. Fourth. One tenth, or less Part, of a Cubic Inch of Oil of Lavender so subtilised, as to scent a Space of 3 Thousand 456 million Times its natural Bulk, ——— *Shewn by Experiment.* ——— What a surprizing Divisibility is this!

A Num-

A Number of other Experiments might be produced.—But Instances of this Kind are endless.

Of MOTION.

47. The next Thing necessary, preparatory to our Enquiries in *Philosophy*, is to consider the *Laws of Motion* given us by Sir *Isaac Newton*.

Law 1st. Every Body in Proportion to its Quantity of Matter perseveres in its present State of Rest, or of uniform Motion in a right Line, unless it be compelled to change that State by Forces impressed thereon.

48. Definition. The *Momentum or Quantity of Motion*, is the Power or Force by which a moving Body strikes, or endeavours to strike, any Obstacle or Impediment which opposes its Motion.

49. Theorem. This *Momentum*, is as the Velocity multiplied by the Quantity of Matter (or Weight).

50. Law 2d. Whatever Motion or Alteration of Motion is produced in any Body, it is always proportional to, and in Direction of the Motive Force impressed.

51. Corollary 1st. If a Body A, be acted on by two Forces at the same Time, one of which in any Time could carry the Body from A to B, and the other in the same Time from A to C; then if these Bodies both act together, the Body A will in equal Time move from A to D in the Diagonal AD, of the Parallelogram ABCD. Pl. II. Fig. 1. Exp.

C

52. Co-

52. Corollary 2d. Hence may be understood the Composition and Resolution of Forces.

Thus for Example, Pl. II. Fig. 2. if a Power of three hundred Weight acts in the Direction C D, and another of two hundred Weight at the same Time in the Direction C B; make C E equal to 3, C G equal to 2, compleat the Parallelogram and draw the Diagonal F C, which measuring 4, a Power of 4 Hundred Weight acting in the Direction of F C produced, viz. in that of C A will sustain or keep the other Powers in *Equilibrio*. *Exp.*

53. Again, if 4 oblique Powers act on each other. For Example, see Fig. 3, Pl. II. Let the Parallelogram C E a F be compleated, let us suppose C E, 2; C F, 3; and C a, 4; produce a C and make C A equal to a C viz 4; then the Powers drawing in the Directions C F and C E are reduced to one that acts in the Direction C a; and consequently would be balanced by an equal Power in the Direction C A: But a Power in the Direction C A may be resolved by the Parallelogram into two, one acting in the Direction C D the other in the Direction C B. Let C D measure 4, and C B, 1; then will 4 Powers, viz. 2 Hundred in the Direction C E; 3 Hundred in that of C F; 1 Hundred in the Direction C B; and 4 Hundred in the Direction C D, sustain each other, when acting all at once. — *Exp.*

54. Corollary 3d. If a Body moves in a Curve, that Curvature must proceed from some external Cause;

Cause; and whenever that ceases to act, will move on in a right Line; as a Stone moving in a Sling.

55. Corollary 4th. Hence also it is evident that all Bodies which move round a Center, endeavour to fly off from that Center. A familiar Instance of this is Water flying off from a Grinding-Stone in Motion.

56. Law 3d. To every action there is always opposed an equal Re-action: Or the mutual Actions of two Bodies upon each other, are always equal and directed to contrary Parts. — *Exp.*

Whatever draws or presses another is as much drawn or pressed by that other. If you press a Stone with your Finger, the Finger is also pressed by the Stone.

If a Horse draws a Stone by Means of a Rope, all the Force by which they act upon each other, is expressed in the *Tension* of the Rope: But that is the same throughout, and therefore equal at each End, upon the Horse and upon the Stone.

Hence we easily account for Rowing, Swimming and Flying.



LECTURE II.

Of the ATTRACTION *of* COHESION ;

Or that Quality by which the Particles of Matter adhere to each other. Hence the Nature of Glues and Solder.—The Solution of Bodies in Menstruums—Rise of Water in Capillary Tubes, Vegetables, &c.

57. **T**HE Cohæſion of the Parts of Matter, is that Quality by which the Particles of Matter, of which larger Bodies are composed, adhere to each other.

58. The Existence of such a Property in Matter, may be shewn by a great Number of Experiments, some of which are :

1. By the Globular Figure of a small Part of any Fluid.
2. By two Drops of Quickſilver running together.
3. By Cohæſion of two Glaſs Plates.
4. By ditto of Leaden Balls.
5. By ditto of Braſs Planes.
6. By a Boy's Clitch Bob, or Sucker.
7. By Nature of Glue and Solder.
8. By making Looking-Glaſſes.

59. That this Power acts only at Contact of the Particles, or at Diſtances indefinitely ſmall, is evident by Experiments of Trituration, or reducing Bodies to Powder.

60. This

60. This also appears from Experiments of an opposite Kind, viz. by re-compounding and uniting the broken Parts of Bodies. by the Interposition of something, which by connecting them together shall attract the several Particles, to form solid Bodies again. Thus, Water unites the Parts of Flour into Dough and Bread, and loose Earth into Bricks.

61. Hence it may be observed, that, though in common Discourse we say such a Thing may be made of Brass, Silver, or any other Matter, as if the Difference of Bodies consisted in the different Kind of Matter it was made of, yet it is much more reasonable to consider with Sir *Isaac Newton* all Matter as homogeneous: And also, that the great Variety of Bodies, and the different Changes which we see happen in them, depend on the Situation, Distance, Magnitude, Figure, Structure, Power and Cohæsion of the Parts of which they are compounded.

62. The Attraction of Cohæsion may also be illustrated by the rising of Water between Glass Plates,

——— *Exp.*

63. Particles of Water are attracted more by Glass than by each other.

64. Particles of Mercury are more attracted by themselves than by Glass.——— *Exp.*

65. By the *Attraction of Cohæsion*, the most considerable Operations in *Chemistry* may be naturally accounted for.

Thus, in the Solution of Bodies in Menstruums, nothing more is required, than that the Particles of

the Medium attract those of the Solid with a greater Force, than the Particles of the Solid attract each other.——*Exp.*

66. As Attraction has its Use in Chemistry, so has also Repulsion.

Thus by the Action of Heat of common Fire, or of the Sun assisted by the Wind, the Particles of Water on the Surface of Seas, Rivers, Lakes, &c. being separated beyond the Sphere of each others Attraction, immediately repel each other; and when so separated, having larger Interstices become lighter than Air, and therefore, as will be shewn in Hydrostatics, must ascend, 'till the Vapour arrives at that Part of the Atmosphere whose specific Gravity is equal to that of the Vapour, where it will float about in the Form of Clouds.

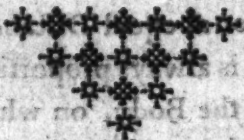
67. Hence also appears the Reason of *Distillation* and *Sublimation*, &c. in Chemistry; being nothing more than a Fluid or Solid Body having its Particles separated by the Heat of Fire, beyond their Sphere of Attraction; and so put into a repelling State; in which they rise from the Subject in a Steam, and are by the Recipient condensed again into Liquor, or collected into a Body of fine impalpable Powder, called Flowers, Sublimate, &c.

68. From what has been already premised, it seems more than probable that *Hardness*, *Softness*, and *Fluidity* of Bodies, depend on the Figures of their component Particles. For the greater their touching Surfaces are, the more strongly will they adhere together,

gether, and form solid Bodies. If they touch each other but in a few Points, they will easily yield to an external Pressure, and form what we call soft Bodies. If they are globular, they can only touch in one Point, and so the Force of Cohesion being the least possible, they will be put into Motion with the least Force, and form a Fluid.

69. By the Attraction of Cohesion, *Water rises in Capillary Tubes, but Quicksilver is depressed.*—Hence also, we see the Reason of the Rise of Water, &c. in Sponge, Sugar, Sand, &c. Also the Nature of the Capillary Siphon, Filtre, and Rise of Sap in Vegetables.—*Exp.*

70. The Sap rises thro' the Body of the Tree, and returns between the Bark and Wood.—*Exp.*



LECTURE III.

The Attraction of Gravity or Weight of Bodies—Laws of falling Bodies—Projectiles or throwing of Bombs—Nature of Pendulums—Center of Percussion—Expansion of Metals—Center of Gravity—and Nature of the Balance.

OF ATTRACTION OF GRAVITY.

71. **T**HOUGH this Principle, as will appear in our Astronomical Lectures, is diffused through the Solar System, yet at present, we shall consider it only with respect to our Earth.

As it will be proved hereafter that the Earth has a diurnal Rotation round its Axis, it is manifest, that, was it not for this Power whereby all Parts of the Earth tend towards its Center, the Particles of which it is composed, would fly off, like Water from a Grindstone.

72. This Power at equal Distances from the Center of the Earth, is always proportional to the Quantity of Matter in the Body, on which it acts.

73. The Gravity or Weight of a Body at any Place between the Surface of the Earth and its Center, has been shewn by Sir *Isaac Newton* to be directly as the Distance from the Center.

74. Gravity on the Surface of the Earth, and any Distance above it, has also been shewn to decrease in the same Proportion as the Square of the Distance increases.

75. As

75. As the Height of the highest Tower from which we can make Experiments of falling Bodies, bears no sensible Proportion to the Earth's Radius, therefore the Force of Gravity at the Top of the Tower, or at the Bottom, cannot sensibly differ.— Hence in Experiments on falling Bodies, or Projectiles, it may always be supposed equal.

76. If a heavy Body be let fall freely from a State of Rest, it will in the first Second of Time fall 16 Feet and a Tenth, and the Space described in the next Second of Time will be three Times as much, in the third Second five Times, and so on as the odd Numbers 1, 3, 5, 7, 9, &c. — *Actual Exp. mentioned.*

77. The Spaces described by falling Bodies are as the Squares of the Times. Thus for Example, if a Body falls 16 Feet in the first Second; in two Seconds it falls four Times as far, (4 being equal to 2 multiplied by 2, or the Square of 2) and therefore would have described a Space of 64 Feet. — In 3 Seconds it would have fallen through 3 multiplied by 3, equal to 9 Times 16 Feet, equal to 144 Feet, and so on for any other Time.

This and following explained by proper Schemes.

78. The Velocities acquired by the Fall of heavy Bodies are always as the Times.

79. Hence also the Velocities are as the Square Root of the Spaces described.

What is meant by Square Root, is no more than the Number, which multiplied by itself will produce the

the given Number. Thus for Example, 2 is the Square Root of 4, for 2 multiplied by 2 is equal to 4.

Of PROJECTILES.

80. If a Shot be fired out of a Gun, or any projected Body be acted on by an uniform projectile Force, and the Force of Gravity at the same Time, it will not then describe a right Line, but (abstracting from the Resistance of the Air) a Curve, called by Mathematicians a Parabola.

This Curve is the same as is described by the running of Liquor out of a Cask, on turning the Cock.

The Doctrine of Projectiles being a Subject too difficult for a popular Lecture, I shall only take Notice, that an Angle of Elevation of 45 Degrees, will throw a Ball the greatest Distance on an horizontal Plane, which Distance is called the Amplitude.

Of PENDULUMS.

81. The Curve called by Mathematicians a *Cycloid*, may be conceived to be generated by the Motion of a Nail in the Attire or Band of a Coach-wheel, when the Coach is driving over plain Ground.—*Illustrated by Exp.*

82. If a Pendulum vibrates in a Cycloid, the Time of Vibration will be the same, whether it describes longer or shorter Arcs.—*This and the next Article shewn by an Exp.*

83. If

83. If a Pendulum vibrates between cycloidal Cheeks, the Bob or Weight will move in a Cycloid, and therefore by the last Article, always vibrate in equal Times, be the Vibrations long or short.

84. As a common Clock describes but a small Arc, the Arc must very nearly coincide with the Curve of the Cycloid, and consequently the Vibrations must be nearly equal.

85. A Pendulum 39 Inches and two Tenths in Length, is found (in England) to vibrate Seconds.

86. The Times of Vibrations of Pendulums of different Lengths, are as the Square Roots of their Lengths. Thus, a Pendulum of 39 Inches and two Tenths in Length, vibrating Seconds, another of one Fourth of that Length, viz. 9 Inches and eight Tenths, will vibrate in half a Second.—*Exp.*

87. By such a Pendulum, the Distance of Thunder may be easily computed, by counting the Number of Vibrations between seeing the Lightning and hearing the Sound. For Sound moves about 1142 Feet in a Second of Time.

88. The Weight of the Bob makes no Alteration in the Time of Vibration of Pendulums.—*Exp.*

Of CENTER of PERCUSSION and OSCILLATION.

89. If a Cylindric Rod be suspended as a Pendulum, it will vibrate in the same Time as a Bob Pendulum which is two Thirds of its Length; and therefore

therefore, that Part of the Rod is called the *Center of Oscillation*.——*Exp.*

90. Hence, the whole Force of the Rod may be considered as collected into that Point, which is $\frac{2}{3}$ Thirds of its Length from the Point of Suspension, and may, therefore, be also called the *Center of Percussion*: Because, if a Person strikes a Blow with that Point, it will be greater than if struck with the End, or any other Part.

91. All Kinds of Metal contract with Cold and lengthen by Heat, and therefore, in hot Weather, the Pendulums of Clocks will be too long, and in Cold too short.——*Shewn by Exp. on a curious Pyrometer.*

Of CENTER of GRAVITY.

92. *Center of Gravity* is that Point in a Body, about which all its Parts exactly balance each other; and therefore in Effect, the Weight of the whole Body may be conceived, to be collected into that Point.

93. If a Beam be suspended by its *Center of Gravity*, it will rest in any Position.——*Exp.*

94. But if the same Beam be suspended by an Axle passing thro' a Hole directly over the *Center of Gravity*, the Beam will rest *only* in an horizontal Position.——*Exp.*

95. When the *Center of Gravity* is supported, the Body will not fall.——*Exp.*

96. The *Center of Gravity* always endeavours to descend: Notwithstanding the Appearance of the Double Cone and Cylinder moving up an inclined Plane.——*Exp.*

97. If

97. If a Line be let fall perpendicular to the Horizon from the Center of Gravity, it is called the Line of *Direction*; because, if the Body was carried downwards by the Force of Gravity, the Center of Gravity would describe that Line.

If this Line falls within the Base of a Body, it stands; if without, it falls.—Several *Exp.*

98. Hence appears the Reason why, whilst some Bodies slide down an inclined Plane, as Cubes, others, as Globes or Cylinders roll.—*Exp.*

99. The Center of Gravity of a regular Polygon or Circle, is in the Center of Magnitude, or Point as nearly as possible every Way equally distant, from all the external Parts of the Body.—*Exp.*

100. The Center of Gravity of a Triangle, is found, by bisecting two Sides of the Triangle by Lines drawn from the opposite Angles.

For the common Interfection of these Lines is the Center required.—*Exp.*

101. The Center of Gravity of an irregular Figure may be easily found mechanically.—*Shewn by Experiment.*

Of the BALANCE or COMMON SCALES.

102. A *Balance* is a strait Line or Beam moveable on a fixed Point.

103. In the *Balance* and *Steelyard*, there will be an *Equilibrium*, when the Weight multiplied by the Length of the Arm on one Side, is equal to the

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Product

Product of the Weight and Length of the Arm on the other Side. — *Exp.*

104. If in a Pair of Scales, the Arms are unequal, it makes a deceitful Balance, and is readily discovered, by changing the Weights from one Scale to another. — *Exp.*

105. If several Weights are hung on the Arms of a Balance, there will be an Equilibrium when the Sum of the Products of the Weights into their respective Distances on one Side, is equal to the Sum of the like Products on the other Side of the Axis. — *Exp.*

106. In Balances or Scales, the Center of Gravity should be a little below the Center of Motion or Axis. — *Exp.*

107. The Arms of a true Balance or Scales should be both of equal Length.

108. The Points from which the Scales are suspended ought to be in the same right Line as the Center of Gravity, that no Part of the Weights may be lost in an oblique Direction.

The Friction on the Axis should be the least possible, in order to which, the Axis should be as small, and the Arms of the Beams as long, as the Weight it is to sustain will admit of.





LECTURE IV.

Of MECHANICS, commonly so called.

*Explaining the Nature of Levers, Pulleys, Wheel and Axis ;
—Inclined Plane—Compound Machines; viz. Wedge,
Screw, Wheel-Carriages, Crane, Jack, Pile-Engine, and
Machine for cutting off the Piles under Water. —Also of
Friction.*

Of LEVERS.

109. **T**HE Lever differs only from the Balance in the Manner of using it ; — and is of three Kinds. — 1. When the Fulcrum or fixed Point on which it turns is between the Weight and Power.

To this Kind may be reduced, Oars and Rudders of Ships, also Scissars, Pincers, Snuffers, &c. A Hammer or bended Lever to draw Nails, may be looked on also as a Lever of this Kind.

110. Second. When the Fulcrum is at one End, the Power at the other, and the Weight between them.

To this Kind may be reduced cutting Knives fixed at one End, and Doors moving on Hinges, and the Hebstock, a Machine used in Germany for the same Purposes as our Hand-Screws.

111. Third. Sort of Lever is, when the Fulcrum is at one End, the Weight at the other, and the Power or Hand between them. But this, as the Power

must be greater than the Weight, is never used but in Cases of Necessity, such as in the Case of Ladders, which being fixed at one End, are by the Force of a Man's Arms raised against a Wall.

112. In all these, there will be an Equilibrium, when the Product of the Weight into its Distance from the Fulcrum, is equal to the Product of the Power into its Distance from the Fulcrum; or in other Words, when the Weight and Power are reciprocally as their Distances from the Fulcrum. *Shewn by Experiment.*

Of the HAND-BARROW.

113. When two Men carry a certain Weight on a Barrow; then, as the Length of the Barrow between the two Men, is to the whole Weight, so is the Length from the Center of Gravity of the Weight to either Man, to the Part of the Weight sustained by the other Man.—*Exp.*

114. In the Multiplying Lever, or several connected together, the Power to the Weight, will be in a ratio compounded of all the Powers to all the Weights, in the several Levers of which it is compounded.—*Exp.*

Of PULLEYS or BLOCKS.

115. An upper Pulley adds no Force, but only lessens the Friction, by causing the Rope to run ore easily.—*Exp.*

116. If

116. If there be moveable under Pulleys added, each under Pulley doubles the Velocity of the Power.—*Exp.*

117. And in these, as in other Machines, there will be an Equilibrium, when the Velocity of the Weight multiplied by the Weight, is equal to the Power multiplied by the Velocity of the Power.

Of the WHEEL and AXLE.

118. Of this Kind, is the common Wheel for raising Water out of a Well; Capstanes and Windlasses of Ships, &c.

In these there will be an Equilibrium, when the Radius of the Axis is to the Radius of the Wheel, as the Power is to the Weight.

Of the INCLINED PLANE.

119. A steep Hill up which any Weight is to be drawn, may be looked on as an inclined Plane.

In this, there will be an Equilibrium, when the Weight is to the Power as the Length of the Plane is to its Height.—*Exp.*

120. Hence, the Force by which a rolling Body descends on an inclined Plane, is to the Force of its absolute Gravity whereby it would fall in free Space, as the perpendicular Height of the Plane is to Length of the Plane.

121. Hence also, a Body acquires the same Velocity by falling down the inclined Plane, as if it

fell directly through the perpendicular Height of the Plane.

Of COMPOUND MACHINES.

122. The *Wedge* for splitting Wood, &c. is generally called one of the simple Mechanic Powers, viz. the 5th. but improperly, as it cannot Act without the Percussion of the Sledge, or Hammer.— And therefore, what has been generally given by most Authors relating to the Wedge, is very little to the Purport. For as its Force depends chiefly on the Weight and Velocity of the Hammer, it is sufficient only to remark, that the less the Angle of the Wedge is, the easier it will enter, or keep the Sides of the Wood open, without flying back.

Of the SCREW.

123. The *Screw* is generally called the 6th simple Power, but improperly also, being really a Compound Machine, as it cannot be used without the Lever.

And here will be an Equilibrium, when the Weight is to the Power, as the Space described in one Revolution by the End of the Lever, to which the Power is applied, is to the Distance between the Threads of the Screw, that is, the Height to which the Weight would be raised by one Revolution of the Screw.

124. In this, as as well as in the Wedge, the Friction is very considerable, and also of great Use;

Use; for by it the Screw is kept in its Position, when any Body is required to be strongly pressed, otherwise it would fly back to its first Position.

125. In Jacks, Cranes, and all compound Machines, the Weight is to the Power, as the Velocity of the Power is to the Velocity of the Weight.
—*Exp.*

Of WHEEL-CARRIAGES.

126. To treat fully of *Friction*, and the Conveniencies and Inconveniencies of different Kinds of *Wheel-Carriages*, would require a Lecture of itself.

I shall therefore only observe, of *Friction*.

That the Resistance arising from *Friction* will remain unvaried, whatever be the Magnitude of the rubbing Surfaces, provided the Weight and Roughness of the moving Bodies remain the same.
—*Exp.*

127. And with Respect to *Wheel-Carriages*, that the Weight or Load being placed on the largest Wheels, will be easier drawn than if on the lower Wheels, for a large Wheel is easier drawn over an Obstacle than a less one. — *Exp.*

128. I might now discourse on the Strength and Stress of Timber, Nature of Arches and Butments for Bridges, &c. as I sometimes do, when I read in the Academy; but have omitted it, as it has not yet been read on by any other Person, and would take up rather too much Room in this Abridgment.

LECTURE V. and VI.

The Principles of Geography explained, with the Construction and Use of various Kinds of Maps and Charts.—

The Use of the Globes, with the Phænomenon of the Har-vest Moon, and some Geographical Paradoxes.

129. **G**EOGRAPHY is the Art of describing the Figure, Magnitude, and Position, of the several Parts of the Surface of the Earth,

130. The *Earth* is a spherical, globular or round Figure; and is usually called the *Terraqueous Globe*.

131. The principal Circles and Appurtenances of the Globes or Armillary Sphere; are. First, the *Axis* is an imaginary Line passing thro' the Center of the real Globe of the Earth, upon which the whole Frame thereof is supposed to turn round. See Plate II. Fig. 5.

Second. The *Poles* are the two Extremities of the *Axis*, one whereof is term'd the *North* or *Arctic*, and the other the *South* or *Antarctic*.

132. Third. The *Horizon* is that great Circle which divideth the Globe into two equal Parts, term'd the upper and the lower Hemispheres; and is represented by the upper Surface of the wooden circular Frame, encompassing the Middle of the Globe.

133. Fourth. The *Meridian* is that great Circle which passing through the two Poles, divideth the
Globe

Globe into two equal Parts, term'd the Eastern and Western Hemispheres. The Brazen Meridian is that Ring or Hoop in which the Globe hangs.

134. Fifth. The *Equator* or *Equinoctial*, is that great Circle which divideth the Globe into two equal Parts, called the Southern and Northern Hemispheres. *Note.* When we speak of the Terrestrial Globe we say the Equator, but with Relation to the Celestial Globe, the *Equinoctial*.

135. Sixth. The *Ecliptic* is a great Circle which crossieth the Equinoctial in two opposite Points called *Aries* and *Libra*, making an Angle therewith equal to the Sun's greatest Delination, viz. equal to $23^{\circ} 28'$. In this Circle the Sun (according to Appearance) always moves. It is divided into 12 Parts called Signs, and every Sign is 30 Degrees.

The Names and Characters of the Signs are as under :

	Latin Names.	English Names.	Marks.
Northern	Aries	Ram	♈
	Taurus.	Bull	♉
	Gemini	Twins	♊
	Cancer	Crab	♋
	Leo	Lion	♌
	Virgo	Virgin	♍
Southern	Libra	Balance	♎
	Scorpio	Scorpion	♏
	Sagittarius	Archer	♐
	Capricornus	Goat	♑
	Aquarius	Water-Bearer	♒
	Pisces	Fishes	♓

136. The Sun, Moon, and Planets are distinguished by these Characters. ☉ for Sun, ☿ Mercury, ♀ Venus, ⊕ Earth, ☾ Moon, ♂ Mars, ♃ Jupiter, ♄ Saturn.

137. On the Globes the Ecliptic is readily distinguished from the Equator, not only by the different Colours wherewith they are stained, but also by the Ecliptic's approaching towards the Poles, after its Interfection with the Equator.

138. Seventh. The two *Tropics* are lesser Circles of the Sphere $23^{\circ} 28'$ distant from the Equinoctial; that on the North Side is called the *Tropic of Cancer*, and the Sun moves in it (according to Appearance) on the 21st of June, and makes the longest Day and shortest Night, to all the Northern Inhabitants. The other Tropic, on the South Side of the Equinoctial, is called the *Tropic of Capricorn*, to which the Sun (apparently) comes about the 21st of December, and then makes the shortest Days and longest Nights, to all the Northern Inhabitants. But to People in South Latitude, the contrary.

139. Eighth. The *Polar Circles* are lesser Circles $23^{\circ} 28'$ distant from each Pole. That Circle near the North Pole is called the *Arctic Circle*; and that about the South Pole the *Antarctic Circle*.

140. Ninth. The *Horary or Hour Circle*, is a small Circle of Brass divided into Hours and Quarters: It is fixed on the Brazen Meridian equally distant from the North End of the Axis, to which, an Index

dex is fitted, that points out the Diviſions of the Hour Circle, as the Globe is turned about.

141. Tenth. The *Quadrant of Altitude*, is a thin Slip of Braſs, one Edge of which is graduated into 90 Degrees, equal to thoſe of the Meridian. When it is faſtened by the Screw to the Meridian, in the Zenith, it represents a vertical Circle, paſſing through any Point.

142. *Latitude* of a Place on the Earth, is the Diſtance of that Place from the Equator, reckoned in Degrees and Parts of a Degree on a Meridian. Here the Learner ſhould have before him a Map of the World, or a Terreſtrial Globe.

On the North Side of the Equator it is North Latitude; and on the South Side, it is South Latitude.

143. As Latitude begins at the Equator where it is nothing; ſo it ends at the Poles, where the Latitude is greateſt, or 90 Degrees.

144. *Parallels of Latitude* are Circles parallel to the Equator. Every Place on the Earth has its parallel of Latitude.

145. *Difference of Latitude* is an Arc of a Meridian, contained between the Parallels of Latitude of two given Places; ſhewing how far one of them is to the Northward or Southward of the other.

146. The Difference of Latitude can never exceed 180 Degrees.

147. *Longitude* of any Place on the Earth, is an Arc of the Equator, contained between the Meridian

ridian of the Place, and the *First* or General Meridian, whence Longitude is reckoned to begin.

Note. We shall begin our Longitude from the Meridian that passes through London.

148. *Difference of Longitude* is an Arc of the Equator intercepted between the Meridians of two Places, shewing how far one of them is to Eastward or Westward of the other.

As Longitude begins at the Meridian of some Place, and is counted from thence both Eastward and Westward, the Difference of Longitude can never exceed 180 Degrees.

149. When two Places have Latitudes both North, or both South; or have Longitudes both East, or both West; they are said to be of the same or like Name: But when one has North Latitude, and the other South, or if one has East Longitude, and the other West, then they are said to have contrary, or unlike Names.

150. The Ancient Geographers, and even some Moderns, reckon their Longitude all round the World East, so that the Place from whence they counted their Longitude, was both in 0° Longitude and in 360° of Longitude. Geographers at this Day make use of different Meridians to count their Longitudes from, thus, the English for the most Part count from the Meridian of London; the French, some from Paris, others from Ferro one of the Azores or Western Islands. These Things are frequently the Cause of Error and Confusion, to such Persons

Persons as are but little acquainted with Geography, or Navigation.

151. The Earth is by Geographers divided into Zones, viz. 2 Frigid, 2 Temperate, and 1 Torrid or Burning Zone. Pl. II. Fig. 7.

The two *Frigid Zones* are comprehended between the Polar Circle and the Poles.

The two *Temperate*, between the Polar Circles and the Tropics.

The *Torrid*, between the two Tropics.

152. A *Parallel Sphere*, Pl. II. Fig. 4. is that Position of the Globe which hath these three Properties: 1. The Poles in the Zenith and Nadir, that is, one directly over Head, the other directly under Foot. 2. The Equator in the Horizon. 3. The Tropics and other Parallel Circles, parallel to the Horizon. The Inhabitants of this Sphere are those (if any) who live under the two Poles.

153. A *Right Sphere*, Pl. II. Fig. 6. is when the Poles are in the Horizon; then the Equator passeth through the Zenith and Nadir. And the Parallel Circles are perpendicular to the Horizon.—The Inhabitants of this Sphere, are those who live under the Equinoctial.

154. An *Oblique Sphere*, Pl. II. Fig. 5. hath these three Properties, viz. 1. One of the Poles above, the other under the Horizon. 2. The Equator partly above, and partly under the Horizon. 3. The Parallel Circles cutting the Horizon obliquely.—The Inhabitants of this Sphere, are all those who

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live

live in any Parts of the Globe except the Poles and Equinoctial.

155. A *Climate*, is a Space of the Earth's Surface, parallel to the Equator, where the Length of the Day is *Half an Hour* longer in the Parallel which bounds it on the North, than in that which terminates it on the South.

156. The *Antæci* are those Inhabitants of the Earth, who live under the same Meridian, but on opposite Parallels, and are therefore equally distant from the Equator. Their Noons are at the same Time; the Days of one are equal to the Nights of the other; and their Seasons of the Year are contrary.

157. The *Periæci* are those People who live under the same Parallel, but opposite Meridians. The same Pole is elevated and depressed to both; they are equally distant from the Equator, and on the same Side. When Noon to one, it is Midnight to the other.

158. The *Antipodes* are those who live under opposite Parallels and Meridians. They are equally distant from the Equator on different Sides; have the contrary Poles equally elevated; the Noon of one, is the Midnight of the other; and when it is the shortest Day to one, it is the longest to the other; and the Seasons of the Year are contrary.

159. The Inhabitants of the *Torrid Zone* are frequently called *Amphiscii*, because their Shadows fall on both Sides of them.

160. Those

160. Those of the *Frigid Zones* are called *Perisii*, because their Shadows fall all round them.

161. And the Inhabitants of the *Temperate Zones* are called *Heterosii*, because they cast their Shadows only one Way.

162. As to the Construction and Use of Maps and Charts, it would take up too much Room to be here particularly described, I shall therefore only mention the several Maps which I generally shew in my Lectures, and pass on to the Use of both the Globes; referring their Explanation to mine, or some other Course.

1. The Stereographic Hemispherical Maps, commonly called the Map of the World.

2. Stereographic Maps of the World on the Plane of the Equator.

3. Orthographic Projection.

4. The Globular Projection.

5. A Map of a Kingdom, as England.

6. Of a County, as Devon, (surveyed by the Author.)

7. A Map of a Country round a City, (as the Author's round Bristol.)

8. Murdock's Map.

9. Plane (Sea) Chart.

10. Mercator's (Sea) Chart.

163. The Distance of two Places on the Plane Chart is readily found by a Scale annexed.—And the Use of a Mercator's is frequently given on the Chart itself.

164. As to finding a Place on the Charts, it is readily done by the Latitude and Longitude of the Place (which may be found in Books called Gazetteers) in nearly the same Manner as on the Globe, which we now hasten to.

The Use of the TERRESTRIAL GLOBE.

165. The principal Problems of the Terrestrial Globe are,

Prob. 1. By the Latitude and Longitude of a place to find it on the Globe.

Solution. Find the Longitude of the Place on the Equator, then bring that Place to the Meridian, and under the Degree of Latitude, counted from the Equator on the General (or Brazen) Meridian, you will find the required Place.

For Examples, find London in 0° Longitude and $51^{\circ} 2'$ Degrees of North Latitude.

Also Port-Royal in Jamaica, in $76^{\circ} 32'$ of West Longitude, and $17^{\circ} 40'$ North Latitude.

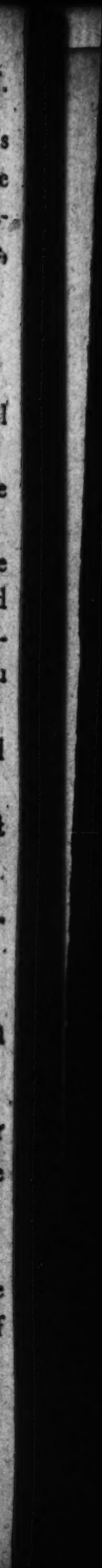
166. Prob. 2. To find the Latitude and Longitude of any Place on the Globe.

This being only the Reverse of the last Problem need not be particularly described.

167. Prob. 3. To find the Angle of Position or Bearing, and Distance of any two Places on the Globe.

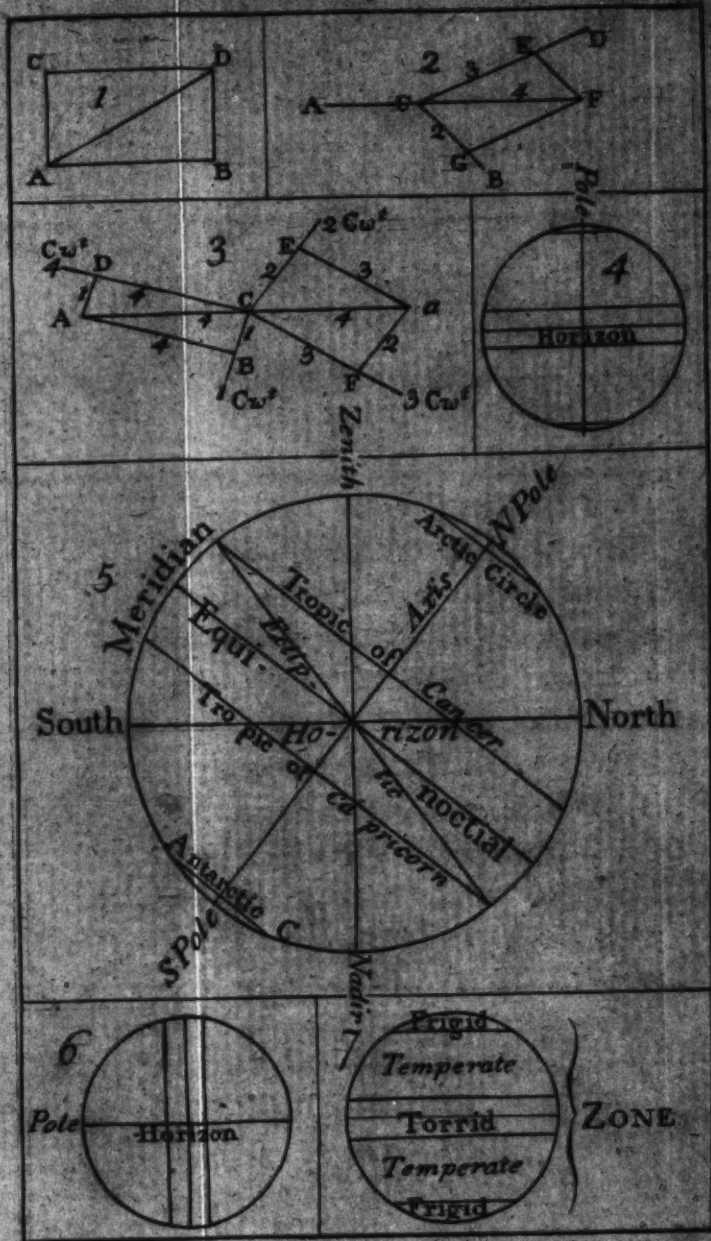
For Example, from London to Jamaica.

First elevate the North Pole equal to the Latitude of



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of London 51 Degrees and a half. Then turn the Globe 'till London comes to the General Meridian, and it will then be in the Zenith. Keep the Globe in that Position, and screw on the Quadrant of Altitude directly over it, on the Meridian. Then turn the Quadrant about till it passes over Jamaica, and counting the Degrees on the Quadrant, between the Zenith and Jamaica, we shall find the Distance * 68 $d \frac{1}{2}$ Degrees; and on the Horizon the Bearing of the Line of Position will be found to be West $\frac{1}{2}$ a Point to the North.

But if we now elevate the Pole equal to the Latitude of Jamaica, and bring it to the Zenith, &c, we shall then find London will not have the direct opposite Bearing from Jamaica, but will bear N. E. b N. $\frac{1}{2}$ East.

This Difference in the Bearing is caused by the Meridians not being parallel but inclined to each other, so as to meet in the Poles.

168. Though the Line of Position, or nearest Distance between two Places, does not in crossing the Meridians make equal Angles, yet the Course which the Canons find in Navigation does; so that whatever Course it is from one Place to another, it will

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be

* It may be necessary, once for all, to mention, that the Answers to these Problems, being worked on the Globe, may differ something from the exact Truth; and from the same worked on other Globes, as they cannot be constructed to a great Degree of Accuracy. Globes being more useful for conveying Ideas, than for Solutions strictly accurate, which can only be done by Mathematical Calculations;

be the direct opposite back again. The Course or Rhumb Line is a Curve, as may be seen in most Globes, and not an Arc of a great Circle.

Authors and Teachers in general, have not made this necessary Distinction.

N. B. A Degree is 60 Sea Miles, or 20 Sea Leagues; or about $69\frac{1}{2}$ Statute Miles.

Here begins LECTURE VI.

169. Prob. 4. **B**Y the Day of the Month to find the Sun's Place in the Ecliptic.

Solution. Seek the given Day in the Circle of Months on the Horizon, and right against it, in the Circle of Signs, is the Sun's Place.

Thus it will be found that the Sun enters the *Spring Signs*, Aries, March 20. Taurus, April 20. Gemini, May 21. The *Summer Signs*, Cancer, June 21. Leo, July 23. Virgo, August 23. *Autumnal Signs*, Libra, September 22. Scorpio, October 23. Sagittarius, November 22. The *Winter Signs*, Capricornus, December 21. Aquarius, January 20. Pisces, February 18.

170. Prob. 5. By the Sun's Place in the Ecliptic being given to find the Month and Day.

This is only the Reverse of the last, and therefore needs no Explanation; for right against the Sun's Place in the Circle of Signs (on the Horizon) is the Day of the Month in the Circle of Months.

171. Prob. 6. By the Day of the Month to find the Sun's Declination, (that is, how many Degrees the

the Sun is to Northward, or Southward of the Equinoctial).

Solution. Find the Sun's Place in the Ecliptic by Problem 4, then seek the Sun's Place in the Ecliptic on the Globe, and bring that Place to the brazen Meridian, and the Division it stands under, is the Sun's Declination, on the given Day.

N. B. In most Almanacks is a Table of the Sun's Declination, which will afford Examples for Practice.

172. Prob. 7. By the Sun's Declination to find the Month and Day.

This is the Reverse of the last, and is easily solved; for by turning the Globe round, you will see the Degree of Declination on the brazen Meridian will intersect the Ecliptic in two Places; then see what Days answer to those Places by Prob. 5.

N. B. On some late Globes, a Piece of Paper called an Analemma, is pasted on, shewing by Inspection the Declination answering to any Day of the Month.

173. Prob. 8. To find all those Places where it is Noon at any given Hour of the Day in any Place.

Bring the given Place to the Meridian; set the Index to the given Hour; then turn the Globe, till the Index points to the upper XII; and observe what Places lie under the Brass Meridian, for to them it is Noon at that Time.

174. Prob. 2. When it is Noon at any one Place, to find what Hour it is at any other given Place.

Bring

Bring the first given Place to the Meridian, and set the Index to the upper XII, then turn the Globe 'till the other given Place comes to the Meridian, and the Index will point to the Hour required.

Example. When it is Noon at London, it is about Seven in the Morning at Jamaica.

175. Prob. 10. For any given Hour of the Day where you are, to find the Hour of the Day in any other Place.

Bring the Place where you are to the Meridian, set the Index to the given Hour; then turn the Globe about, and when the other Place comes to the Meridian, the Index will shew the Hour of the Day there, as required.

Example. When it is 8 at Night at London, it is almost $\frac{1}{2}$ past 3 in the Morning at Peking in China.

176. Prob. 11. To find those Places to which the Sun is vertical in the Torrid Zone for any given Day.

Bring the Sun's Place to the Meridian, and observe what Degree it cuts; then turn the Globe about, and all those Places which pass under that Degree of the Meridian are those required.

177. Prob. 12. To find what Day of the Year the Sun will be Vertical at any given Place in the Torrid Zone.

Bring the given Place to the Meridian, and mark the Degree exactly over it; then turn the Globe round, and observe the two Points of the Ecliptic which pass under that Degree of the Meridian.

Lastly,

Lastly, see on the Wooden Horizon, on what Days of the Year the Sun is in those Points of the Ecliptic, for those are the Days required.

Thus, at Jamaica the Sun is Vertical on the 10th of May and 2d of August.

178. Prob. 13. To find the Place where the Sun is Vertical when it is any given Day and Hour at a given Place.

Bring the Sun's Place to the Meridian, note the Degree of Declination over it; then bring the given Place to the Meridian, and set the Index to the given Hour; then turn the Globe 'till the Index comes to XII at Noon, and the Place under the Degree of Declination before noted, has the Sun in the Zenith, at that Time.

Example. June 3, when it is 7 o'Clock in the Morning at London, the Sun will be Vertical, or directly over Head to a Place in Latitude 23 and Longitude 75 Degrees East, which falls in India, near the Gulf of Cambay.

179. Prob. 14. To find what Place can see a Transit of Mercury or Venus.

Find the Place where the Sun is Vertical at the given Time, by the last Problem: Bring that Place to the Zenith, then to all the Places which are above the Horizon, it will be Day, or they can see the Sun, and consequently the Transit.—All the Places in the Western Horizon will see the Phenomenon at Sun-rising, those under the Meridian at Noon, and those in the Eastern Horizon at Sun-setting;

setting; those on the Western Side of the Meridian in the Forenoon, and those on the Eastern Side in the Afternoon.

The Transit of Venus which happens this Year 1769, on June the 3d in the Evening, will furnish an Example.—As seen (if possible) at the Earth's Center, according to London Time, it would begin at 7^h. 15'. Middle at 10^h. 25'. End June the 4th at 1^h. 35' Morning. And it will appear that at the Beginning, England is nearer the Eastern Horizon, and will soon after get below it, and consequently the Inhabitants of Great Britain will see but little of it.

180. Prob. 15. To make an Horizontal Dial. Elevate the Pole equal to the Latitude of the Place, then will the Axis of the Globe represent the Gnomon or Style of the Dial: Conceive in your Mind the Paper on which the Dial is to be delineated, to be on the Horizon of the Globe.

Bring any Meridian to lie exactly under the General Meridian; then as the Meridians are drawn at every 15 Degrees of the Equator, they will represent Hours Circles, and therefore we have only to observe how many Degrees these Meridians, or Hour Circles, intersect the Horizon from the General Meridian, or 12 o'Clock Hour Circle.

Thus for Example, in Latitude $51^{\circ} \frac{1}{2}$, which is the Latitude of London, their Distances from the Meridian are as in the annexed Table.

Hours

<i>Hours.</i>		<i>Dist. from Merid.</i>	
<i>Morning</i>	<i>Evening.</i>	<i>d</i>	
XI.	I.	11.	51
X.	II.	24.	19
IX.	III.	38.	3
VIII.	IIII.	53.	36
VII.	V.	71.	6
VI.	VI.	90.	0

Then to construct the Dial, which may be of any Figure, round, square, or multangular.

For Example, suppose a Square, as in Pl. IIII. Fig. 1. Draw a Line VI, VI, to represent the East and West, or VI o'Clock Line; and perpendicular to it A, XII; for the Meridian or 12 o'Clock Line.

About A as a Center, with a Pair of Compasses extended to 60 Degrees on a Line of Chords, describe the Semicircle *b c d*, on which from *c* on each Side towards *b* and *d* set off the Degrees in the above Table, then Lines being drawn from A thro' these Points, and produced to the Sides of the Dial, will be the Hour Lines required. As for the Morning Hours before, and the Evening ones after VI, they are drawn by only producing the others upwards.

As the Elevation of the Pole above the Horizon is equal to the Latitude of the Place, make the Angle *c A e* equal to $51^{\circ} \frac{1}{2}$ for London (or Bristol) then will *c A e* represent the Gnomon, which make in Brass, and fix upright on the Meridian A *c*, so that the Point A of the Gnomon corresponds to the Point A of the Dial.

Lastly,

Lastly, lay this Dial on an Horizontal Plane, where a Meridian or North and South Line is drawn, so that a XII. may coincide with that Line, then will the Shadow of the Gnomon, caused by the Light of the Sun, shew the true apparent Time of the Day.

181. I might now proceed to the Construction of various other Dials, but as it is not my Intention, at present, to treat of Dialling in general, I shall only observe, that a Dial may be conceived to be drawn on any other Plane, either vertical or inclined, in any Angle to the Horizon; by only conceiving the Plane on which the Dial is to be drawn to pass thro' the Globe in that Position; then will the Interfection of the Hour Lines (or Meridians each 15° asunder) cut on the Dial Plane, the Places where the Hour Lines are to be drawn:—And the Elevation of the Pole above that Place, will represent the Height of the Stile or Gnomon.

Of the Use of the CÆLESTIAL GLOBE.

182. Prob. 1. **T**O rectify the Globe for any Place, Day and Hour.

First, Set the Globe upon an horizontal Plane, with its Parts answering to those of the World; move the Meridian in its Notches by raising or depressing the Pole, until the Degrees of Latitude cut the Horizon; then is the Globe rectified for the Latitude.

Second,

Second, Reckon the Latitude from the Equinoctial towards the elevated Pole, there ſcrew the bevel Edge of the Nut belonging to the Quadrant of Altitude, and the Globe is rectified for the Zenith.

Third, Bring the Sun's Place to the Meridian, and ſet the Index to XII, at Noon, (or upper XII,) and the Globe is rectified for Noon; then turn the Globe about 'till the Index points to the given hour, and there ſtop the Globe, it being then rectified for the given Latitude, Zenith, and Time.

189. Prob. 2. To find the Sun's Amplitude, that is, the Point of the Compaſs on which the Sun riſes or ſets.

Rectify the Globe for Noon by Problem 1ſt. Then turn the Globe 'till the Sun's Place touches the Horizon, in the Eaſtern Hemisphere, and it will ſhew on what Point it riſes on the Horizon. And if the Globe be turned 'till the Sun's Place touches the Weſtern Horizon, it will ſhew the Point of Setting.

The ſame Operation ſhews the Time of the Sun's Riſing or Setting, for when the Sun's Place touches the Horizon in the Eaſtern Hemisphere, the Index ſhews the Time of Riſing; as it does the Time of Setting, when the Sun's Place touches the Weſtern Part of the Horizon.

Corollary. Hence alſo may be known the Length of the Day, for the Hours between Sun Riſing and Sun Setting, will be the Time the Sun continues above the Horizon, or Length of the Day. And if the Length of the Day be ſubtracted from 24
F Hours,

Hours, the Remainder will be the Length of the Night.

Example. On June 20th at London, Lat. $51^{\circ}\frac{1}{2}$, the Sun's Amplitude is 40° from the East or West Points, that is, the Sun rises $E\ 40^{\circ}\ N$, and sets $W\ 40^{\circ}\ N$; which is nearly $NE\ \frac{1}{2}\ E$, and $NW\ \frac{1}{2}\ W$.—The Sun rises that Day about $3^h\frac{1}{4}$, and sets about $8^h\frac{1}{4}$. And consequently the Day (equal to double the Sun-setting, is) $16^h\frac{1}{2}$. And Length of the Night (equal to double Sun-rising, is) $7^h\frac{1}{2}$.

184. Prob. 3. To find the Length of the Day in any Place where the Sun does not set every 24 Hours.

Example. Suppose at Hacluit's Headland in Greenland, Latitude 80° North.

Elevate the Pole equal to the Latitude of the Place, then turning the Globe on its Axis, you will find that 26 Degrees of Aries, when it comes under the North Meridian, will touch the Horizon, but not set; and that no other Degree of the Ecliptic will descend so low as the Horizon, 'till you come to the 4th Degree of Virgo; therefore all the Time the Sun is passing from the 26th Degree of Aries, to the 4th Degree of Virgo, the Sun does not set; viz. from the 16th of April to the 27th of August.

185 Prob. 4. To find the Sun's Altitude and Azimuth at any given Hour of the Day at any Place.

Having rectified the Globe to the Latitude and Time, lay the Quadrant of Altitude over the Sun's Place, and you will see the Sun's Altitude; and the

End

End of the Quadrant of Altitude will shew the Azimuth on the Horizon.

Example. At London, Lat. $51^{\circ} \frac{1}{2}$, at 3 in the Afternoon, the Sun's Altitude is 43° , and his Azimuth WSW.

186. Prob. 5. By taking the Altitude of the Sun by a * Quadrant, to find the Hour of the Day.

Rectify the Globe for the Latitude, Day and Hour, and screw on the Quadrant of Altitude; then, if it is in the Forenoon, bring the Sun's Place and graduated Edge of the Quadrant together, on the Eastern Side of the Meridian; if in the Afternoon, on the Western Side; then, if the Sun's Place in the Ecliptic cuts the Degree of Altitude on the Quadrant, the Hour Index will shew the Time; but if not, move the Globe till it does.

For Example, take the Reverse of that in the last Case.

187. Prob. 6. By the Right Ascension and Declination of any Star to find its Place on the Globe.

Find the right Ascension on the Equinoctial, and bring it to the General Meridian; then under the Declination you will find the required Star.

188. The following Table of Right Ascensions, adapted to the Beginning of the Year 1775, will furnish a Number of Examples; and will be sufficiently exact for working on the Globe for 70 Years to come, and even then be more accurate than most Globes are constructed.

FIG. 20. TABLE OF THE Names

* Common Quadrants for this Purpose are sold by the Author, price Three Shillings.

Names of the Stars.	Charac.	Magn.	Rt. Asc.		Dec.	
			o	'	o	'
Extremity of the Wing of Pe- gusus, <i>Algenib</i>	γ	2	0	25	13	56 N
In the Head of the Phoenix			3	46	43	32 S
The bright Star in the Tail of the Whale	c	2	8	5	19	14 S
In the Girdle of Andromeda			14	17	34	25 N
The Spring of the River Eri- danus, <i>Archenar</i>	α	1	22	20	58	23 S
In the Jaw of the Whale			42	38	3	11 N
In the Head of Medusa, <i>Algol</i>	c	2	43	15	40	4 N
The bright Star of Perseus			47	5	49	2 N
The South Eye of the Bull, <i>Aldebaran</i>	α	1	65	46	16	2 N
The bright Star in the left Shoulder of Auriga, <i>Capella</i>			75	1	45	45 N
The bright Foot of Orion, <i>Rigel</i>	c	1	75	49	8	28 S
The North Horn of the Bull			77	51	28	24 N
The Western Shoulder of Orion	γ	2	78	16	6	8 N
Bright Star in the Dove			82	53	34	13 S
The Eastern Shoulder of Orion	α	1	85	45	7	21 N
The bright Star in the Ship Argo, <i>Canopus</i>			94	44	52	34 S
The bright Star in the Dog's Mouth, <i>Sirius</i>	α	1	98	49	16	25 S
In the Head of the North- ern Twin, <i>Castor</i>			110	3	32	22 N
The little Dog, <i>Procyon</i>	α	1	111	53	5	48 N
In the Head of the Southern Twin, <i>Pollux</i>			112	53	28	34 N
Bright Star in the Oars of the Ship Argo	c	1	137	40	68	47 S
The Heart of the Female Hydra			139	8	7	42 S

Names of the Stars.	Char.	Magn.	Rt. Asc.		Dec.	
			°	'	°	'
The Lion's Heart, <i>Regulus</i>	α	1	149	5	13	3N
In the Great Bear	α	2	162	25	62	58N
The Lion's Tail	ϵ	2	174	24	15	50N
Foot of the Crossiers	α	1	183	34	61	51 S
The Virgin's Spike	α	1	198	21	9	51 S
The last Star in the Tail of } the great Bear	η	2	204	40	50	27N
West. Foot of the Centaur	ϵ	2	207	2	59	16 S
Bright Star in Bootes, <i>Arcturus</i>	α	1	211	21	20	22N
Bright Star in Eastern Foot } of the Centaur	α	1	216	10	59	54 S
Southern Scale of Libra	α	2	219	37	15	6 S
Northern Scale of Libra	ϵ	2	226	14	8	32 S
Bright Star of the Crown	α	2	231	17	27	29N
Northernmost Star in Scor- } pion's Forehead	ϵ	2	238	6	19	10 S
Scorpion's Heart, <i>Antares</i>	α	1	243	54	25	54 S
In the East. Knees of Ophiucus	η	2	254	23	15	26 S
Head of Ophiucus	α	2	261	7	12	44N
Bright Star of the Harp, <i>Lyra</i>	α	1	277	20	38	35N
Bright Star of the Eagle, <i>Athair</i>	α	2	294	57	8	17N
Eye of the Peacock	α	3	301	56	57	26 S
Tail of the Swan	α	2	308	26	44	29N
Westernmost wing of the Crane	α	2	328	30	48	2 S
In Southern Fish, <i>Fomalhaut</i>	α	1	341	17	30	49 S
In the Shoulder of Pegasus	ϵ	2	343	18	26	52N
In the Wing of Pegasus, <i>Markab</i>	α	1	343	23	14	00N
The Head of Andromeda	α	2	359	12	27	50N

F 3

189. Prob.

189. Prob. 7. To find the Amplitude of a Star, the Time of its Rising, Southing, and Setting, and Time of Continuance above the Horizon.

Having rectified the Globe for the Latitude and Sun's Place in the Ecliptic, turn it about till the Star comes to the Eastern Horizon, for the Rising, and to the Western for Setting, as in Problem 20. for the Sun.

Example: Thus, October 10th at London, Aldebaran, a Star in the 1st Magnitude in the Bull, will be found to rise about 8 o'Clock at Night ENE.—On S. Meridian about $3^h \frac{1}{4}$ in the Morning; and set about WNW about $10^h \frac{1}{4}$ in the Forenoon.—And consequently, continues above the Horizon about $14^h \frac{3}{4}$.

190. Prob. 8. To find the Altitude and Azimuth of a Star at any given Hour of the Night.

Having rectified the Globe for the Latitude of the Place; the Place of the Sun in the Ecliptic and Time; the Quadrant being brought to pass over the Star, will shew its Altitude and Azimuth.

Example. Suppose it was required to find the Altitude and Azimuth of Syrius, or Dog-Star, of the first Magnitude, on December 15th, at 10 in the Evening at London? Answ. Altitude 10° , Azimuth SE.

191. Prob. 9. To find the Time of the Night by the observed Altitude of a Star.

This being only the Reverse of the last, as the 5th Problem was of the 4th, needs no particular Description.

192. Scho-

192. Scholium. "The antient Poets make frequent mention of the Stars Rising and Setting *Cosmically*, &c. A Star is said to *rise* or *set Cosmically* when it *rises* or *sets* at *Sun-rising*; and when it *rises* or *sets* at *Sun-setting*, it is said to *rise* or *set Acronically*. A Star *rises Heliacally* when first it becomes visible, after it had been so near the Sun as to be hid by the Splendor of his Rays: And a Star is said to *set Heliacally*, when it is first immerfed, or hid by the Sun's Rays. The *Fixed Stars*, and the three superior Planets, Mars, Jupiter, and Saturn, *rise Heliacally* in the Morning: But the Moon *rises Heliacally* in the Evening; because the Sun is swifter than the superior Planets, and slower than the Moon."—*Harris on Globes*, p. 80. 4th Edit.

193. As to the Planets, after looking in an Almanack or Ephemeris, for their Places in the Ecliptic, and Latitude, that is, how much above or below the Ecliptic, it is only to put on a Patch to represent the Planet, and then work as for the Stars. Hence the following Problem for the Planets will require no particular Instructions.

194. Prob. 10. To find the Rising, Southing, and Setting of the Planets and Moon. The Almanacks will furnish Examples enough, particularly the Royal Ephemeris, or White's or Parker's Ephemeris.

N. B. As the Planets Places are calculated in the common Ephemerides for Noon, and as the Moon's Motion in a few Hours is sensible, moving about
half

half a Degree an Hour, it would be proper to make two Workings for the Moon; first, by the Place in the Ephemeris to find nearly the Time; then, by making the Moon's Place so many half Degrees less, or more, as the Time is Hours before or after the nearest Noon, work again, and the Time will be more accurately determined.

195. Prob. 11. To find the Beginning, Ending, and Duration of Twilight.

The Sun when Twilight begins or ends, is supposed to be 18 Degrees below the Horizon, therefore we have only to find when the opposite Point to the Sun's Place in the Ecliptic, is 18 Degrees above the Horizon.

Example. At London, on the 1st of October, Day breaks, or Twilight begins at $4^h \frac{1}{4}$, and the Sun rises at $6^h \frac{1}{4}$; therefore the Duration of Twilight in the Morning is 2 Hours; and being the same again in the Evening after Sun-set, will be in all 4 Hours. Which added to the Length of the Day $11^h \frac{1}{4}$, gives from Day-break to dark Night 15 Hours and a half. — N. B. From the End of May to the Middle of July there is no dark Night at London.

196. Prob. 12. To account for the Phenomenon of the Harvest Moon.

In order to this we need only consider, that on the 20th of March, when the Sun is in the Beginning of Aries, the Full Moon on that Day must be in the Beginning of Libra: And since when the Sun sets, or Moon rises, on that Day, those Equinoctial
Points

Points will be in the Horizon, and the Ecliptic will then make the greatest Angle therewith; the Part or Arch which the Moon describes in one Day, viz. 13 Degrees, will take up about an Hour and a Quarter ascending above the Horizon; and therefore, so long will be the Time after Sun-set the next Night, before the Moon will rise.

But at the opposite Time of the Year, when the Sun is in the Autumnal, and Full Moon in the Vernal Equinox, as on the 23d Sept. the Ecliptic will, when the Sun is setting, make the least Angle with the Horizon; and therefore, 13 Degrees will in this Case soon ascend, viz. in about a Quarter of an Hour; and so long after Sun-set will the Moon rise the next Day after the Full: Hence, at this Time of the Year, there is much more Moon Light than in the Spring: For which Reason, the Full Moon next before the 23d of September is called the Harvest Moon, and the next after, the Hunter's or Shepherd's Moon: All which is clearly shewn on the Globe.

197. Prob. 13. To represent the Appearance of the Heavens at any Time and Place, very useful to know the Stars and Planets by.

Rectify the Globe for the Latitude, Zenith, and Time of the Night, and it is done.

Then the Quadrant of Altitude being laid over any Star, will shew both its Altitude and Azimuth, that is, the Height above the Horizon in Degrees, and on what Point of the Compass it bears; by which it may be easily found in the Heavens.

Thus

Thus have we given in a compendious Manner, as the Nature of an Epitome required, the most useful Problems of the Globes, and if the Reader makes himself Master of these, he will not find much Difficulty, in solving such others, as may fall in his Way.

N. B. *As many of the foregoing Problems are solved on the Globes, in the Lectures, as Time will admit.*

198. We shall conclude our Lectures on Geography and the Use of the Globes with the following Collection of PARADOXES.

Paradox 1. There are two Places on the Earth, in which there is only one Day and one Night throughout the whole Year.

Par. 2. There are also some Places on the Earth in which it is neither Day nor Night for 24 Hours.

Par. 3. There is a certain Place on the Earth of a considerable Southern Latitude that hath both the greatest and least Degree of Longitude.

Par. 4. There is a Place, where the Winds, tho' frequently veering round the Compass, do always blow from the North.

Par. 5. There is a certain Place, where at a certain Time of the Year, the Sun's Amplitude at his Rising being a certain Number of Degrees from the North; on the same Forenoon his Azimuth shall be first a less Number of Degrees from the North, and afterwards a greater Number, than his Amplitude at his Rising.

This is the only Place of the Compass, where it may be easily found in the Hemisphere.

This was first solved by me many Years since, in the Gentleman's Magazine.

Par. 6. There is a Place 60 Leagues distant from a Ship, bearing due North. A Ship sailing 30 Leagues North, and 90 Leagues South, will strike the Island.

This I made some Years since, on seeing an impossible one, in a certain ingenious Author.

Par. 7. There is a certain Island in the Baltic Sea, to whose Inhabitants the Sun is visible in the Morning before he riseth and likewise in the Evening after he is set.

Par. 8. There is a certain Village in the Kingdom of Naples, situated in a Valley, and yet the Sun is nearer to the Inhabitants thereof every Noon by 3000 Miles and upwards, than when he either riseth or setteth to those of the said Village.

Par. 9. There is a vast Country in Ethiopia Superior, to whose Inhabitants the Body of the Moon doth always appear to be most enlightened when she is least enlightened, and to be the least when most.

Par. 10. There are Places on the Earth where the Sun and Moon and all the Planets do actually rise and set, according to their various Motions, but never any of the Fixed Stars.

Par. 11. If London bears East from Bristol, Bristol cannot bear exactly West from London.

Par. 12. It is possible for two Persons to be on board the same Ship, and yet one shall sail more Leagues than the other, during the same Voyage.

199. *A Table of the Latitudes and Longitudes (from the Royal Observatory at Greenwich near London) of some of the principal Places of the Earth.*

Names of Places.	Lat ^d .	Long.
	0	0
Alexandria in Egypt	31 11 N	30 16 E
Athens in Greece	38 5 N	23 52 E
Babylon in Egypt, Grand Cairo	30 0 N	42 46 E
Berlin in Brandenburg	52 33 N	13 26 E
Bristol in England	51 26 N	2 28 W
Cape of Good Hope in Africa	33 56 S	18 29 E
Cadiz in Spain	36 31 N	6 1 W
Carthagenæ in America	10 27 S	75 26 W
Copenhagen in Denmark	55 41 N	12 45 E
Dantzick in Poland	54 22 N	18 31 E
Island of St. Helen	15 55 S	5 49 W
Jerusalem	31 55 N	35 20 E
London at St. Paul's	51 31 N	0 51 W
Lisbon in Portugal	38 42 N	9 7 W
Moscow in Russia	55 45 N	37 46 E
Naples in Italy	40 51 N	14 14 E
Observatory at Greenwich	51 28 N	0 0
Observatory at Paris	48 50 N	2 20 E
Observatory at Vienna	48 13 N	16 22 E
Petersburg in Russia	59 56 N	30 20 E
Pekin in China	39 54 N	116 22 E
Port Royal in Jamaica	18 0 N	76 45 W
Prague in Bohemia	50 4 N	14 45 E
Rome at St. Peter's	41 54 N	12 29 E
Venice in Italy	45 25 N	12 4 E
Upsal in Sweden	59 52 N	17 42 E

LECT.

200. Before we proceed to our Lectures on Astronomy, in order to render this Epitome a proper Introduction to Geography for the Use of Schools, we shall give a compendious Account of the natural and political Division of the Earth.

Of the Natural Division of the EARTH.

201. The Earth's Surface is naturally divided into Land and Water.

202. The *Land* into 1. Continents. 2. Islands. 3. Peninsulas. 4. Isthmuses. 5. Promontories. 6. Mountains.

203. The *Water* into 1. Oceans. 2. Seas. 3. Gulfs. 4. Straits. 5. Lakes. 6. Rivers.

204. By cutting out the several Parts of Land and Water from the Papers which cover Mr. *Senex's* Terrestrial Globe of 28 Inches Diameter, and weighing them separately in an exact Balance, Mr. *Martin* found the Weight of the Paper for Land was 367 Grains.

Ditto for the aqueous Surface 1125 Grains. -

And as the Surfaces must be in Proportion to their Weight, the Surface of Water is to that of Land, as 1 to $3\frac{7}{10}$. So that if the Surface of the whole Earth be divided into 4 Parts, three of them are covered with Water, and only one with Land.

205. CONTINENTS are very large Tracts of Land, containing several Kingdoms; and are commonly reckoned 4. viz. Europe, Asia, Africa, and Ame-

rica. These Divisions are frequently, but very improperly, called the four Quarters of the World.

206. An ISLAND is Land surrounded on every Side by Water, as Great Britain, Ireland, &c.

207. A PENINSULA is a Part of Land almost surrounded by Water, being only connected to some other Land, by a narrow Neck, called an ISTHMUS. Thus South America may be considered as a Peninsula, being only joined to North America by the Isthmus of Darien.

208. A PROMONTORY is a Mountain or high Hill, stretching itself into the Sea, the Extremity of which is called by Sailors a *Cape* or *Head-land*.

209. An OCEAN is a large Collection of Salt Water, separating Continents from each other.

210. A SEA, is a large Quantity of Water, but less than an Ocean, washing some particular Shores.

211. A GULF or BAY is a lesser Part of an Ocean, something resembling the Letter C, contained between two Shores, which surround it on every Side, except at its Entrance, where it communicates with the Sea. The larger are generally called *Gulfs*, the lesser *Bays*.

212. A STRAIT is a narrow Entrance from a greater into a lesser Sea. As for Instance, the Straits of Gibraltar, leading into the Mediterranean Sea.

213. A LAKE is a large Quantity of Water, or kind of inland Sea, without any visible Communication with the Ocean,—As Lake *Huron* in North America:

214. RIVERS are too well known to need any Definition.

*Of the POLITICAL DIVISION of the Earth
into KINGDOMS, &c.*

Of EUROPE.

215. EUROPE is bounded on the North by the Frozen Sea, on the South by the Mediterranean Sea, on the East by Asia, and on the West by the Western Ocean. It lies between the Latitudes of 72° N. and 36° N. and Longitudes 65° E. and 10° W. of London. It is in Length about 3000 Miles, measuring from the NE. to the SW; and in Breadth about 2500 Miles.

216. In the following Table are given the Position of the several Countries from the Middle of the respective Quarter of the World in which they lie. The chief Cities with their Latitudes and Longitudes (from London) to the nearest Degree, being sufficient to find them on the common Maps. As to the Table of Latitudes and Longitudes given in P. 72, they are very correct, being collected from Astronomical Observations.

Abbreviations. E. stands for Empire; K. Kingdom; R. Republick; D. Dutchy; El. Electorate; P. Principality.

Countries.	Position.	Chief Cities.	Lat.	Long.
K. Denmark	NW.	Copenhagen	56N	13 E.
R. Dutchland	W.	Amsterdam	52	5 E.
K. England	W.	London	52	0
K. France	W.	Paris	49	2 E.
E. Germany	Mid.	Vienna	48	16 E.
K. Hungary	Mid.	Prefburg	48	17 E.
K. Ireland	W.	Dublin	53	7 W.
K. Italy	S.	Rome	42	13 E.
E. Muscovy	NE.	Moscow	56	38 E.
or Ruffia		Peterfburg	60	30 E.
R. Netherlands	W.	Bruffels	51	4 E.
K. Norway	NNW.	Bergen	60	6 E.
K. Poland	Mid.	Warsaw	52	21 E.
K. Portugal	SW.	Lifbon	39	9 W.
K. Scotland	W.	Edinburgh	56	3 W.
K. Sweden	N.	Stockholm	59	18 E.
R. Switzerland	Mid.	Bern	47	7 E.
K. Spain	SW.	Madrid	40	4 W.
E. Turkey	SE.	Constantinople	41	29 E.

217. In Europe are four Kingdoms besides those abovementioned ; but they are included in the aforementioned Countries.

The Kingdom of *Bohemia*, a Part of Germany, its chief City Prague, in Lat. 50° N. and Long. 15° E.

218. *Pruffia*, a Part of Poland, the King's Residence is at Berlin a City in Germany, Lat. 53° N. Long. 13° E.

219. *Sardinia*, an Island belonging to Italy, in Lat. 40 N. and Long. 9 E ; the King resides at Turin, Lat. 45^d N. Long. 7^d E.

220. The Kingdom of the *Two Sicilies*, belonging to Italy, the King resides in Naples, a City in Italy, Lat 41° N. Long. 14° E,

221. The

221. The principal States in Germany are,

States.	Chief City.	Lat.	Long.
D. Austria	Vienna	48° N	16° E
El. Bavaria	Munich	49 N	11 E
K. Bohemia	Prague	50 N	12 E
El. Brandenburg	Berlin	53 N	14 E
El. Cologne	Cologne	51 N	7 E
El. Hanover	Hanover	53 N	10 E
P. Hesse Cassel	Cassel	51 N	9 E
El. Mentz	Mentz	50 N	8 E
El. Palatine	Manheim	50 N	8 E
El. Saxony	Dresden	51 N	13 E
El. Triers	Triers	50 N	6 E
D. Wurtenburg	Stutgard	49 N	9 E

222. The principal States in Italy are,

States.	Chief City.	Lat.	Long.
R. Genoa	Genoa	44° N	9 E
R. Lucca	Lucca	44 N	11 E
D. Mantuan	Mantua	45 N	12 E
D. Milanese	Milan	45 N	9 E
D. Modenese	Modena	45 N	12 E
K. Naples	Naples	41 N	15 E
D. Parmesan	Parma	45 N	12 E
Patriarchate	Rome	42 N	13 E
P. Piedmont	Turin	45 N	7 E
D. Savoy	Chambery	46 N	6 E
D. Tuscany	Florence	44 N	12 E
R. Venice	Venice	46 N	13 E

223. The principal Seas, Gulfs, and Bays in Europe are,

The *Adriatic Sea*, between Italy and Turkey.

The *Baltic Sea*, between Denmark, Poland and Sweden.

The *Bay of Biscay*, between France and Spain.

The *English Channel*, between England and France.

The *Euxine* or *Black Sea*, in Turkey, between Europe and Asia.

The *German Ocean*, between Germany and Britain.

The *Gulf of Bothnia*, in the NE. Parts of Sweden.

The *Gulf of Finland*, between Sweden and Russia.

The *Gulf of Venice*, the NW. End of the Adriatic Sea.

The *Mediterranean Sea*, between Europe and Africa.

The *White Sea*, in the NNW. Parts of Muscovy.

224. The principal Islands in Europe are,

The *AZORES* or *Western Islands*, belonging to Portugal, in Lat. 38° N. and Long. 29° W.

The *BRITISH ISLES*; viz. Great Britain, Lat. 54° N. Long. 3° W. Ireland, Lat. 52° N. Long. 8° W. Orkneys North of Scotland, Lat. 61° N. Long. 1° W. The Western Islands, NW. of Scotland, Lat. 53° N. Long. 7° W. Isle of Man, Lat. 54° N. Long. 4° W. Isle of Angelsey, Lat. 53° Long. 4° W. Isle of White, South of England, Lat. 51° N. Long. 2° W. And the Scilly Islands off the Land's-End of England, Lat. 50° N. Long. 7° W.

DANISH ISLES. East and West Greenland near the North Pole, as yet doubtful whether Islands or not. Ferro Isles, Lat. 62° N. Long. 5° W. Iceland, Lat. 65° N. 19° W. Zeland in the Baltic Sea, Lat. 56° N. Long. 12° E.

ITALIAN ISLES in the Mediterranean Sea, Corfica, Lat. 42° N. Long. 9° E. Lipari Isles, Lat. 39° N.

N. Long. 15° E. Sardinia, Lat. 40° N. Lon. 10° E. Sicily, Lat. 37° N. Long. 14° E.

SPANISH ISLES in the Mediterranean Sea, Ivica, Lat. 39° N. Long. 1° E. Majorca, Lat. 40° N. Long. 3° E. Minorca (belonging now to England) Lat. 40° N. Long. 4° E.

SWEDISH ISLES, Isles of Aland, Lat. 60° N. Long. 20° E, Gothland, Lat. 57° N. Long. 17° E. Oeland, Lat. 57° N. Long. 16° E. Rugen, Lat. 55° N. Long. 14° E.

TURKISH ISLES, in the Mediterranean, Archipelago Isles, Lat. 38° N. Long. 24° E. Candia, Lat. 35° N. Long. 25° E.

Of ASIA.

225. ASIA is bounded on the North by the Northern or Frozen Ocean, on the South by the Indian Ocean, on the East by the Pacific Ocean or South Sea, and by Europe and Africa on the West. It lies between the Latitudes of 72° North and 10° South. Its Length exclusive of its Islands is about 4800 Miles, and Breadth about 4300 Miles.

Asia contains the following Cities and Countries.

Countries

Countries	Posit	Chief Cities	Lat.	Long.
Arabia —	SW	Medina	25° N	40° E
Bukharia or Ufbecs	Mid.	Samarkand	40 N	66 E
Chinese Tartary	E	Chynian	42 N	118 E
E. China	SE	{ Pekin	40 N	116 E
		{ Nankin	32 N	119 E
		{ Canton	23 N	113 E
India East the Gan- ges - - - -	S	{ Ava	25 N	141 E
		{ Pegu	17 N	97 E
		{ Siam	13 N	101 E
India West the Gan- ges - - - -	S	{ Cambodia	11 N	105 E
		{ Agra	27 N	77 E
		{ Delli	29 N	76 E
Karazm - -	Mid.	Urjenz	41 N	96 E
K. Korea —	E	Kingkitau	38 N	123 E
E. Persia —	S	Ispahan	32 N	53 E
E. Siberia —	N	{ Tobolski	58 N	68 E
		{ Astracan	47 N	49 E
K. Syria —	W	Aleppo	36 N	37 E
K. Thibet —	Mid.	Ekerdu	35 N	75 E
E. Turkey —	W	Smyrna	38 N	27 E

226. In some of these Countries are contained others.

ASIATIC TURKEY contains,

Countries	Posit.	Chief Cities	Lat.	Lon.
Curdistan or } Assyria }	E	Betlis	32° N	43° E
Desart of Arabia	S			
Diarbec —	E	Moufol	35 N	44 E
Eyraca —	SE	Bagdat	32 N	46 E
Georgia —	N	Testis	42 N	48 E
Natolia —	W	Smyrna	38 N	29 E
Syria —	W	Aleppo	36 N	37 E
Turcomania or } Armenia }	E	Erzerum	40 N	41 E

227. INDIA

227. INDIA WEST THE RIVER GANGES contains,

Countries	Pos.	Ch. Cities	Lat.	Lon.
Coromandel Coast	Bisnager or Carnate } E. Side K. Golconda K. Orixá	S Madras Golconda Orixa	13 N 16 N 20 N	80 E 77 E 80 E
Malabar Coast	Decan Bisnager W } or Carnate }	SW Goa Calcut Cochin	16 N 12 10	74 E 70 E 76 E
Northern Parts	Bengala } Cambaya } or Guzaret } Indoſtan	SE S N Patna Surat Delli	26 N 21 N 29 N	88 E 73 E 81 E

228. INDIA EAST THE GANGES contains,

Countries	Posit.	Chief Cities	Lat.	Long.
K. Ava	NW	Ava	20° N	96° E
K. Cambodia	S	Cambodia	13 N	105 E
K. Cochín China	E	Thoanoa	16 N	108 E
K. Laos	N	Lanchan	18 N	101 E
K. Malacca	S	Malacca	3 N	101 E
K. Pegu	W	Pegu	17 N	94 E
K. Siam	S	Siam	15 N	100 E
K. Tonquin	NE	Keccio	18 N	103 E

229. The

229. The principal Seas, Gulfs, and Bays in Asia are,

Bay of Bengal, between India East, and India West the Ganges.

Bay of Siam, formed by the Countries of Siam and Malacca.

Caspian Sea is surrounded by Siberia on the N. Korazm on the the East, Persia on the South, and Georgia on the West.

Gulf of Persia, having Persia on the NE. and Arabia on the SW.

Korean Sea, between Korea and the Islands of Japan.

Yellow Sea, between China and the Japan Isles.

230. The principal Islands belonging to Asia are,

Islands	Chief Isle	Chief City	Lat.	Long.
Chinese Isles	Hainan	Tan	20 N	109 E
	Formosa	Taywanfa	24 N	121 E
	Makaho	Makau	22 N	113 E
Japan Isles	Bongo	Bongo	30 N	139 E
	Japan	Jeddo	36 N	140 E
	Tonfa	Tonfa	33 N	141 E
Moluccos	Celebes	Macasser	5 S	118 E
	Ceram	Ambay	3 S	129 E
	Gilolo	Gilolo	1 N	127 E
Philippines	Luconia	Manila	16 N	121 E
	Mindanao	Mindanao	7 N	126 E
	Samar		12 N	124 E
Sunda Isles	Borneo	Banjar	0	114 E
	Java	Batavia	7 S	109 E
	Sumatra	Achin	5 N	94 E

Adaman

Adaman Iſles, to the Weſt of Siam, Lat. 13° N. Long. 92° E.

Ceylon Iſland, SE. of Biſnagar; the chief City, Candy or Candy Uta, Lat. 7° N. Long. 81° N.

Ladrome or Marian Iſlands, chief Iſland Goam, Lat. 13° N. Long. 142° E.

Maldivè Iſlands, SW. of Biſnagar, Lat. 5° N. Lon. 75° E.

Nicobar Iſles, Weſt of Malacca, Lat. 7° N. Long. 94° E.

Of AFRICA,

231. This large Continent is a Peninſula, being joined to Aſia by the Iſthmus of Suez. It is bounded on the North by the Mediterranean Sea, on the South by the Southern Ocean; on the Eaſt by the Red Sea and Indian Ocean; and on the Weſt by the Atlantic or Western Ocean.

It lies between the Latitudes of 37° North and 35° South; and Longitudes of 18° Weſt and 54° Eaſt; it is about 4300 Miles long and 4200 Miles broad.

232. The chief Countries and Cities in Africa are as in the annexed Table.

Countries

Countries	Posit.	Chief Cities	Lat.	Long.
E. Abyssinia } or Ethiopia }	E	Ambamarjan	13° N	35° E
K. Adel	E	Zeila	11 N	44 E
K. Algiers	N	Algiers	37 N	2 E
K. Angola	SW	Loando	7 S	14 E
K. Barca	N	Docra	32 N	27 E
K. Benguela	SSW	Benguela	12 S	11 E
K. Benin	SW	Benin	7 N	5 E
Bidfara	SW	Bidfara	6 N	18 E
Biledulgerid	Mid. N	Dara	29 N	12 E
K. Congo	SW	St. Salvador	13 N	18 E
K. Egypt	NE	Cairo	30 N	32 E
Guiney	SW	Cape Coast	4 N	0 E
K. Loango	SW	Loango	3 S	11 E
Mandinga	W	James Fort	37 N	76 W
E. Morocco	NW	Fez	38 N	6 W
Negroland	Mid.	Tombute	14 N	1 W
Nubia	Mid.	Nubia	19 N	33 E
Sofala	SE	Sofala	20 S	38 E
K. Tripoli	N	Tripoli	35 N	36 E
K. Tunis	N	Tunis	37 N	10 E
Zanguebar	E	Melinda	3 S	40 E

233. Many Parts of the Coast of Africa are in Subjection to the European Kingdoms.

The Kingdoms of Algiers, Barea, Egypt, Tripoli, and Tunis, are either subject to the Ottoman or Turkish Empire, or acknowledge themselves under its Protection.

Abyssinia is governed by its own Emperor.

Ajan or *Anian* is inhabited by a few Arabs.

Caffaria or Country of Hottentots, in which is the Cape of Good Hope, belongs to the Dutch.

The

The *Coast of Guiney* is divided into several Parts, called the *Gold Coast*, *Grain Coast*, *Ivory Coast*, *Sierra Leone*, and *Slave Coast*.

The Dutch, English, French, and Portuguese, have Settlements all along these Coasts, and many Miles up the Rivers *Gambia* and *Senegal*.

We have very little, if any Knowledge, of the interior Parts of *Africa*, and therefore the particular Boundaries of Kingdoms, &c. in this Part of the World, are not to be relied on, unless on or near the Sea Coasts.

234. The principal Seas, Gulfs, and Bays in *Africa* are,

The *Bight of Benin*, on the Coast of *Guiney*.

Red Sea, between *Africa* and *Asia*.

Mosambique Sea, between the Continent of *Africa* and the Island of *Madagascar*.

Saldana Bay, near the Cape of Good Hope.

235. The principal African Islands are,

Islands	Chief Isle	Ch. Town	Lat.	Lon.
Canary Isles	Canaria	Palma	29° N	19° W
Cape Verd Isles	St. Jago	St. Jago	15° N	23° W
In Ethiopian Sea	St. Helena	James Fort	16° S	6° W
Madeira Isles	Madeira	Funchal	33° N	16° W
Socotera	Socotera	Calansia	12° N	53° E

Madagascar is one of the largest Islands in the World, it lies in the Indian Ocean, Lat. 20° S. Long. 45° E. It is divided into a Number of little States, some of

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them

them formed by the European Privateers and Pirates, and their Descendants.

The Island of *Bourbon*, East of Madagascar, in Lat. 21° S, and Long. 53° E. and

Isle of France, in Lat. 30° S. and Long. 55° E. belong both to France.

The *Canary Isles* to Spain.

The *Madeiras* and *Cape de Verd Isles* to Portugal.

And *St. Helena* to England.

Of AMERICA.

236. This vast Continent, being discovered by Christopher Columbus, a Genoese, in the Year 1491, was called the *New World*; and *America* from *Americus Vespucius* a Florentine, who is said to have discovered that Part of this Country which lies under the Equinoctial.

It is usually divided into two Parts, North and South, being joined together by the Isthmus of Darien.

NORTH AMERICA lies between the Latitudes of 10° and 80° North; (so far has been discovered, but it is not improbable that it approaches nearer the N. Pole.) And for the most Part between the Longitudes of 50° and 150° West; its Western Boundary being not accurately known. Its Length is about 4200 Miles from North to South, and 4800 Miles from East to West. It is bounded on the North by

we know not what; on the South by the Gulf of Mexico and the great South Sea; on the East by the Atlantic or Western Ocean, and on the West by the Pacific Ocean.

237. SOUTH AMERICA lies between the Latitudes of 12 Degrees N. and 58 Degrees S. and between the Longitudes of 35 Degrees and 83 Degrees West. It is bounded on the North by the Caribbean or North Sea, on the South by the Southern Ocean; on the East by the Atlantic Ocean, and on the West by the Pacific Ocean. It is about 4200 Miles long, and 2200 Miles broad.

238. The principal Places in North America are, as in the annexed Table,

Countries	Posit.	Chief Towns	Lat.	Long.
California	W	St. Juan	34° S	80° W
Canada	Mid.	Quebec	47 N	70 W
Carolina	SE	Charles Town	33 N	80 W
Florida	S	St. Augustine	30 N	10 W
Georgia	SSE	Savannah	32 N	82 W
Jerseys	E	New York	41 N	75 W
Louisiana	S	Fort Lewis	18 N	176 W
Maryland	E	Annapolis	45 N	64 W
New Britain	NNE	Fort Rupert	51 N	80 W
New England	E	Boston	48 N	70 W
New Mexico	S	Santa Fe	36 N	107 W
New Wales	N	Port Nelson	57 N	94 W
Nova Scotia	NE	Hallifax	45 N	63 W
Old Mexico	SW	Mexico	20 N	104 W
Pensilvania	E	Philadelphia	41 N	74 W
Virginia	E	James Town	37 N	76 W

California, Old Mexico, and New Mexico, belong to Spain.

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Louisiana,

Louisiana, on the West of the River Mississippi, to the French.

And all the other Places to the English.

239. The principal Places in South America are as in the following Table,

Countries.	Posit.	Chief Places	Lat.	Long.
Amazonia	Mid.	River Amazon	0 Deg	48° W
Brazil	E	St. Salvador	12 S	38 W
Chili	SW	St. Jago	34 S	72 W
Guiana	NE	Surinam	6 N	55 W
La Plata	SE	Buenos Ayres	35 S	58 W
Paraguay	Mid.	Assumption	25 S	58 W
Patagonia	S	Cape Virg. Mary	52 S	76 W
Peru	W	Lima	12 S	77 W
Terra Firma	NW	Panama	9 N	80 W

Amazonia, Guiana, and Patagonia are possessed by the Indians, excepting some Parts of the Coast of Guiana, in the Hands of the Dutch and French.

Brazil belongs to the Portuguese.

Chili, La Plata, Paraguay, Peru, and Terra Firma to the Spaniards:

240. The principal Seas, Gulfs and Bays in America are,

Bay of California, in the Pacific Ocean, having California on the West.

Bay of Campeachy, Part of the Gulf of Mexico, on the Mexican Coast.

Bay of Fundy, in Nova Scotia.

Bay of Honduras, Part of the Caribbean Sea, next to Mexico or New Spain.

Caribbean Sea, has Terra Firma on the South, and the Caribbean Islands, Hispaniola, Jamaica, Cuba, &c. on the North.

Gulf

Gulf of St. Lawrence, between Newfoundland and Nova Scotia.

Gulf of Mexico, formed by Old Mexico, Louisiana, and Florida.

Hudson's Bay, on the NW of Nova Scotia.

241. The principal American Islands in the Atlantic Ocean are,

The ANTILLES. Cuba, chief Town Havanna, Lat. 23° N. Long. 81° W. Hispaniola, chief Town St. Domingo, Lat. 19° N. Long. 70° W. Jamaica, chief Town Kingston, Lat. 18° N. Long. 78° W. and others of lesser Note.

BAHAMA ISLES, lie North of Cuba, in Lat. 25° N. and Long. 78° W.

BERMUDAS, or Summer Islands, East of Carolina, Lat. 32° N. Long. 64° W.

CAPE BRETON, near the Gulf of St. Lawrence, Lat. 47° N. Long. 62° W.

CARIBBEE ISLES. Martinico, Lat: 15° N. Long. 61° W. and others in the Caribbean Sea.

GALLIFAGO ISLES, NW. of Peru, in the Pacific Sea, Lat. 2° S. Long. 94° W.

NEWFOUNDLAND, E. of the Gulf of St. Lawrence, Lat. 50° N. Long. 58° W.

SOLOMON ISLES, a Cluster of 18, the largest of which is named Isabelle, Lat. 11° N. As to Long: Geographers place them so very different as from 125° to 170° East. An astonishing Instance of the Incorrectness of our Maps! But we have Hopes that Longitudes of these and many others will be accurately determined by the Observations on the Transit of Venus, June 3, 1769.

LECT.



LECTURE VII.

ASTRONOMY.

That the Copernican or Solar System will elegantly solve the Phenomena of the Sun, Mercury and Venus, the Motion of the Earth both annual and diurnal.—Cause of the Seasons, Day and Night, Summer and Winter.—Difference between Solar and Siderial Time.—Best Way of regulating Clocks.—Motions of the superior Planets, Mars, Jupiter, and Saturn.—The Truth of the Solar System demonstrated, by shewing that the Earth can neither be at Rest in the Center of the System, nor any where amongst the Planets, and consequently, that it must be in Motion. Proved on an improved Planetarium, &c.

242. **T**HE Design of this, and the two subsequent Lectures, is to explain the principal Phenomena of the Solar System, to prove that the Ptolemaic or Vulgar System, which supposes the Earth to be at rest in the Center, is not the true System, being not agreeable to the Appearances of the Heavens: But that the Copernican, which supposes the Sun to be the Central Body, and the Planets to revolve round it, is agreeable to, and will readily solve all the Phenomena of the Heavens.

243. In order to judge which is the true System, it will be proper to collect what are the principal Appearances

Appearances in the Heavens, as it is from these only the true System can be determined.

244. The Stars appear all at an equal Distance from us: But Reason tells us, that we ought not from hence to conclude that they really are so. Because, as long as we continue in the same Place, we cannot judge accurately of the Distances of very remote Objects.

245. By viewing the Stars, we find some appear to keep always the same Position and Distance from each other, these are called *Fixed Stars*. Others appear to change their Places, and are therefore called *Planets* or wandering Stars. Of the fixed Stars, Globes and Maps have been made. Hence, if any new Object, as a *Comet*, appears in the Heavens, it is easily discovered.

246. The antient Astronomers, for the more readily finding the Stars, divided that Part of the Heavens which was visible to them, into 48 Constellations, named the *Great Bear*, *Little Bear*, *Dragon*, *Cepheus*, &c.

247. These Figures took their Origin from the religious Ceremonies of the *Ethiopians*, *Egyptians*, *Phenicians*, and *Chaldeans*. The *Greeks* adopted a Part, and disguised the rest, by substituting Names from their fabulous History.

248. Those who have sailed to the South, within the last 300 Years, have added 12 Constellations, named *Peacock*, *Crane*, &c. The Figures of these Constellations had no other Origin, than the Fancy of those who named them.

249. The

249. The most antient Observations of the Stars which have descended to us, are those made by *Timocharis* and *Aristillus*, about 300 Years before Christ. About 170 Years after them *Hipparchus* of *Rhodes* made a Catalogue: And 260 Years after, *Ptolemy* of *Alexandria* revised and published his Catalogue containing 1026 Stars, whereof 1022 had been afore determined by *Hipparchus*.—This was the only one used by Astronomers 'till the 16th Century.—Others have been made by *Ulugh Beigh* a Tartarian Prince, *Tycho Brahe*, and *Hevelius*. But for the largest and most accurate Tables we are beholden to two of our own Countrymen and Astronomers Royal, the laborious and ingenious Mr. *Flamsteed*, and the learned Dr. *Halley*.

250. Mr. *Bayer*, a German Astronomer, was the first who distinguished the Stars in each Constellation by the Greek Alphabet.

251. Amongst other Phænomena observed in the Heavens are these following.

First, That the Planets *Venus* and *Mercury* are sometimes seen to pass before the Sun, sometimes to go behind or beyond the Sun, making two Conjunctions an inferior and superior.

252. Secondly, *Mercury* and *Venus* are never seen in Opposition to the Sun, nor indeed very distant from it; *Venus* in its greatest Elongation not exceeding 48 Degrees, and *Mercury* 28; this last is generally so near the Sun, as to be seldom seen, being lost in the superior Brightness of the Sun's Rays.

253. Third,

253. Third, The Planets in different Parts of their Orbits appear of very different Magnitudes. Thus, in particular, Mars sometimes appears as large as Jupiter, at other Times so little as not to be distinguished from a fixed Star, but by the Redness of its Aspect.

254. Fourth, That all the Planets appear to move with different Degrees of Velocity. — Sometimes they appear to move direct or according to the Order of the Signs, (from West to East) then to be Stationary, or to have no sensible Motion; then retrograde, or to go backward, for some Time, then to become direct again, and go on as before.

Many other Phænomena might be added, but these are sufficient to demonstrate the Absurdity of that System, which supposes the Earth to be at rest in its Center; as it will not solve either of these Phænomena.

Of the SOLAR or COPERNICAN SYSTEM.

255. Having shewn that the Ptolemaic System will not solve the Appearances of the Heavens, we now proceed to take a particular Survey of the Solar System, and to shew how elegantly the Phænomena before observed, and all others which have been observed, are illustrated by this System; which is represented Pl. III. The Orbits of the respective Planets are distinguished by their Characters. The Orbits of three Comets are also delineated, with the Years of their Appearances. In the right Corner
are

are given the proportional Magnitudes of the Planets, the Sun being supposed equal to the Orb of Saturn, or about 6 Inches Diameter.—A, is Mercury; B, Venus; C, the Earth; D, Mars; E, Jupiter, with his Belts; F, Saturn, with his Ring.

In the left Corner are given the proportional apparent Diameters of the Sun, as seen from the several Planets. Thus, supposing at Mercury the Sun appears as big as Fig. *a*; in Venus it would appear no bigger than *b*; at the Earth than *c*; at Mars *d*; at Jupiter *e*; and at Saturn *f*.

Of the SUN.

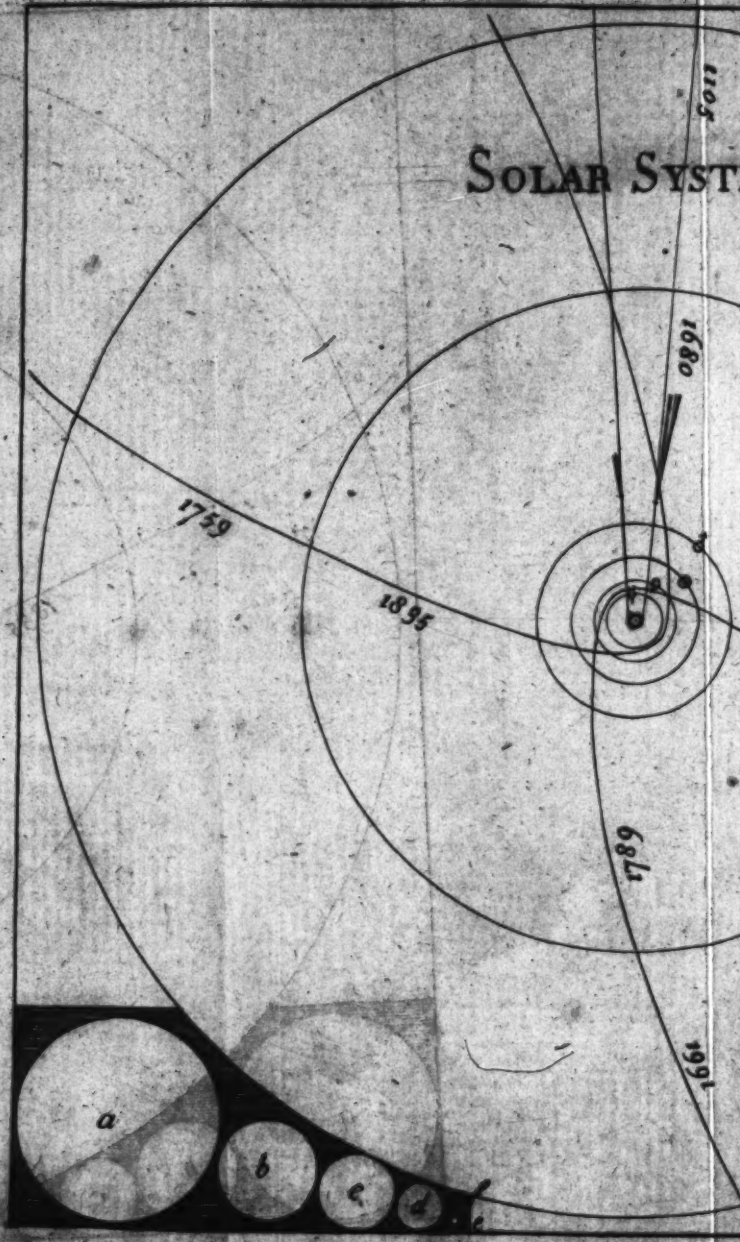
256. The Sun is the Central Body of this System, about which the Earth and other Planets revolve; the Moon round the Earth, 4 Moons or Satellites round Jupiter, and 5 round Saturn.

257. The Sun is in Diameter 895000 Miles, and turns on its Axis in 25^d, 15^h, 16^m.

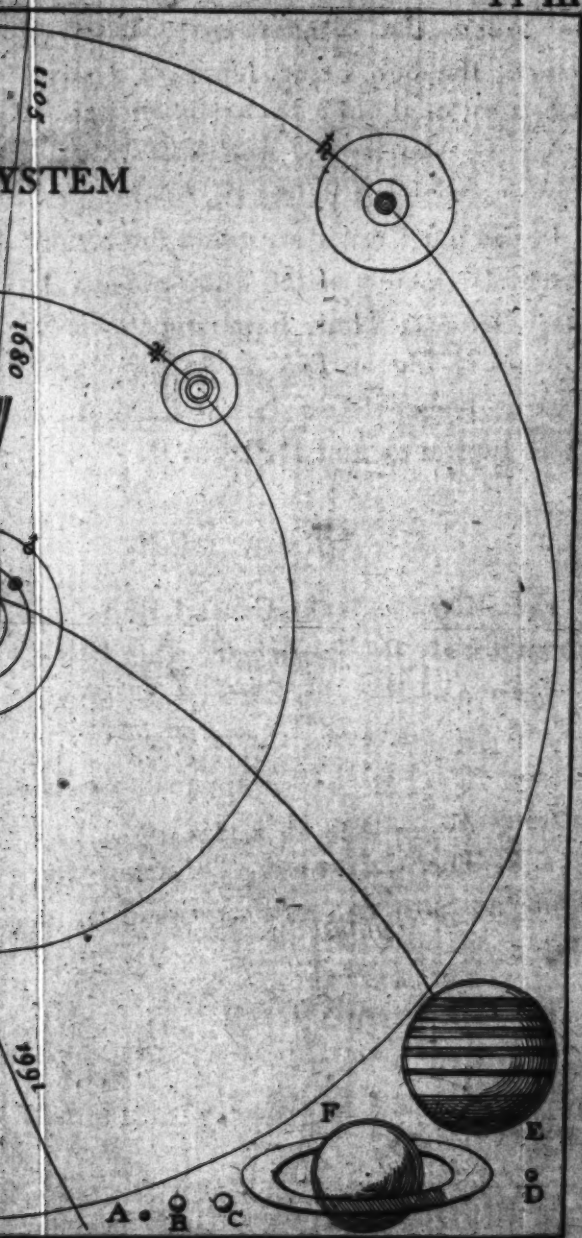
258. The Magnitudes, Distances of the Planets from the Sun, &c. are expressed in the annexed Table.

Planets

SOLAR SYSTEM



P1 III



Planets Names	Mercury	Venus	Earth	Mars	Jupiter	Saturn
Characters or Marks	☿	♀	♁	♂	♃	♄
Colours of the Planets	Spark. Red	Yel. White		Fiery Red	Splen. Whi.	Lum Red
Diurnal Motion, or Length of their Days	Unknown	24 8 *	23 56 4	24 40	9 56	Unknown
Periods or Length of their Years	87 23 16	224 16 49	365 6 9	686 23 27	4332 12 20	10759 6 36
Diameter in Miles	3050	7440	7970	5240	94500	78300
Mean Dist. from the Sun in Miles	36,841,468	68,891,486	95,173,000	145,014,148	494,990,976	907,956,130
Proport. of Light & Heat	7	2	1	$\frac{4}{16}$	$\frac{1}{27}$	$\frac{1}{96}$
Inclination of their Orbits to the Ecliptic	0 54 0	3 20 0	0 0 0	1 52 0	1 20 0	2 39 0
Places of their Node	14 43 8	14 34 II		18 9 of Taurus	8 32 23	21 26 of Cancer
Node	14 43 of Scorpio	14 34 ♄		18 9 ♍	8 32 of Capricorn	21 26 ♏

These Distances of the Planets from the Sun, are calculated by supposing the Sun's Parallax 8' and half, as it was, according to the Observations of the Transit of Venus in 1761. But it is hoped will be more accurately determined, as soon as the Observations of the Transit of Venus, this present Year 1769, can be collected from distant Parts of the World.

* By *Bianchini's* Observations, but according to others, in 23^h, 20'.

259. The principal Phenomenon relating to the Sun are,

First, That the Sun appears to have an annual Motion round the Earth. This is caused by the real annual Motion of the Earth round the Sun.

260. Second, The Sun as well as the Planets and Stars, appears to move daily round the Earth from East to West every Day. This is caused by the real diurnal Motion of the Earth round its Axis.

261. The Times of the Revolutions of the Planets round their Axes are discovered by their Maculae or Spots: And by the Paths these Spots appear to describe over the Disk of the Sun or Planet, the Inclinations of their Orbits are determined.

Of the Planet MERCURY.

262. This is the nearest Planet to the Sun, and we find in this System, that its Motions are agreeable to what really happens in the Heavens.

263. As it has two Conjunctions, an inferior and superior, it follows, that the Orbit of this Planet must be within the Orbit of the Earth, and its greatest Elongation (or Distance it is seen from the Sun) being but 28 Degrees, whereas Venus's is 47°, shews it to be within the Orbit of Venus.

264. As this Planet never appears far from the Sun, it is but seldom seen.— From the Time of his inferior to his superior Conjunction, he rises and sets before the Sun, and therefore will be seen only in the Morning. But from his superior to his inferior

inferior Conjunction, he will rise and set after the Sun, and then can be seen only in the Evening.

Of the Planet VENUS.

265. *Venus* the next Planet in the System, being also an inferior Planet, has in general the same Phenomena as Mercury.

266. When Venus is Westward of the Sun, she rises and sets before him; therefore can only be seen in the Morning, and when to Eastward of the Sun, in the Evening.

267. Venus has Phases like our Moon. These were first observed by *Galileo* with his Telescope.

268. She appears in her greatest Lustre when she is removed from the Sun about 40 Degrees, before and after her inferior Conjunction, though only One-fourth of her illuminated Face is then turned towards the Earth.

Of the EARTH.

269. The apparent Motion of the Sun and Stars round the Earth every 24 Hours, is caused by the real diurnal Motion of the Earth round its Axis.

270. If the Axis of the Earth was not inclined to that of the Ecliptic, the Days and Nights would always be equal, to all Parts of the Earth: But as the Axis of the Earth is inclined to the Ecliptic $23^{\frac{1}{2}}$ and does in the annual Motion of the Earth preserve its Parallelism, it readily accounts for the different

Lengths of Days and Nights, Summer and Winter.

271. The Time from the Sun's being on the Meridian of any Place, and its next appearing on the same Meridian, or a Day, being called 24 Hours, solar Time; the Time elapsed between the coming of a Fixed Star to the Meridian of any Place, and its appearing again on the same Meridian; or which is the same thing, the Time the Earth takes to revolve round its Axis, is $23^h, 56', 54''$, called Siderial Time; the Difference is $9', 54''$ daily.

Hence we know the best Method of regulating Clocks to equal or siderial Time.

Of MARS.

272. Mars is the first superior Planet, or which lies beyond the Earth's Orbit; Venus and Mercury being inferior or within it.

273. It has been already observed, that all the Planets move sometimes direct, sometimes retrograde, sometimes are stationary.—At different times are at different Distances, and therefore appear of very different Magnitudes.

274. A superior Planet hath only one Conjunction, which is a Superior one, whereas an inferior Planet has two.

275. A superior Planet hath an Opposition, but an Inferior hath none.

276. As we observe the Phænomena of Mars to be agreeable to the Motions of a Superior, but not of an Inferior

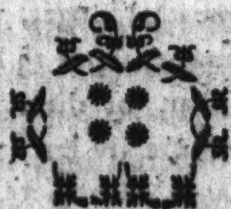
Inferior, it appears, that Mars must be a superior Planet.

277. When Mars is in Conjunction its Face is enlightened like our full Moon, and would appear so, if it did not become invifible, by being in the same Direction as the Sun. At any other Time it appears more than $\frac{1}{2}$ enlightened, or gibbous, refembling our Moon a few Days before or after the Full.

Of JUPITER and SATURN.

278. Jupiter and Saturn being fuperior Planets, their Motion muft be fimilar to thofe of Mars, and therefore, need not be particularly defcribed.

This Lecture concludes with a Proof that the Earth cannot be at Reft any where amongst the Planets, and confequently, that it muft be in Motion, as in the Copernican System.



LECTURE VIII.

Of the Moon.

Of the Motions of the Moon—Eclipses of the Sun and Moon, with the Nature of Transits, particularly the Transit of Venus on the 3d of June, 1769.—Also the Eclipses of the Satellites of Jupiter and Saturn. Illustrated on the Orrery, Planetarium, Tellurian, &c.

279. **T**HE Moon is in Diameter about 2175 Miles; and is, at its mean Distance about $60\frac{1}{3}$ Semidiameters of the Earth, from the Earth; its greatest being $64\frac{2}{3}$, and least $55\frac{1}{3}$.

280. The Time the Moon requires to perform its annual Revolution in its Orbit (with respect to the Stars) is $27^d, 7^h, 43'$, called a *periodical Month*. But as in this Time, the Earth has proceeded forward some Degrees in its annual Course, the Time from one Conjunction to another, called a *synodical Month*, must be somewhat longer, viz. $29^d, 12^h, 44'$. So that the Moon makes about 13 Revolutions round the Earth in a Year, or there are 13 periodical Months; whereas there are but 12 synodical ones.

281. The Inclination of the Moon's Orbit to the Plane of the Ecliptic, is about $5\frac{1}{4}$ Degrees.

282. The Moon's Node has a retrograde Motion, making a Revolution with respect to the first Point of Aries, in 18 Years, 224 Days, 5 Hours.

283. The

283. The Moon is about 300 Times nearer the Earth than the Sun.

284. The Moon's true Diameter, according to Observations, is to that of the Earth as 3 to $11\frac{1}{7}$; hence the Earth must give about 13 Times as much Light to the Moon, as the Moon does to the Earth. And their Solidities are as 27 to 1384, or as 1 to $81\frac{1}{4}$.

285. It may be observed, that the Moon always keeps the same Face towards the Earth, and therefore must turn round its Axis, in the same Time as it performs its Revolution in its Orbit, viz. in $27^d, 7^h, 43'$.

286. The Phases of the Moon prove that she shines by reflected Light of the Sun, and not by any Light of her own,

287. The Moon's Path in absolute Space is every where Concave towards the Sun.

Of ECLIPSES.

288. An *Eclipse* of the *Moon* is caused by the Interposition of the Earth between the Sun and Moon, thereby intercepting the Rays of the Sun from falling on the Moon, and therefore can only be at full Moon.

289. If the Opposition be near a Node, the Eclipse may be total; if at more remote Distances, only partial.—When the Opposition falls more than 12 Degrees from a Node there will be no Eclipse, the Earth's Shadow then either passing above or be-

low the Moon. This shews the Reason why we have not an Eclipse every full Moon.

290. An Eclipse of the Moon appears of the same Quantity of Digits, at all Places where it is visible. And the Difference of Longitude of Places are easily determined, by comparing Observations of the Beginning or End, taken at the Places whose Difference of Longitude is required; for the Difference of observed Time, turned into Degrees, by allowing 15 Degrees to an Hour, will be the Difference of Longitude required: The Eclipse beginning sooner to the Westermost Place, and later at the Eastermost.

291. An Eclipse of the Moon begins on the East Side, and ends on the West.

The MOON less than the EARTH, both less than the SUN.

292. From an Eclipse of the Moon these Corollaries may be made.

Cor. 1st. It is manifest the Moon is an opaque or dark Body, for if it was luminous in itself, it could not be deprived of its Light by the Shadow of the Earth, (which is nothing but the Loss or Privation of the Light of the Solar Rays) any more than a Candle can lose its Luminousness, by being placed in the Shadow of any opaque Body.

293. Cor. 2. If the Earth was equal in Diameter with the Sun, the Earth's Shadow would be indefinitely extended, as it must every where continue of the

the same Breadth; and would be of a Magnitude more than sufficient to eclipse Mars, as it is less than the Earth. This is never the Case, therefore the Earth cannot be equal in Diameter to the Sun.

294. Cor. 3. As the Earth's Shadow never reaches Mars, being of a conical Figure, converging to a Point, before it reaches that Planet, it is evident, the Sun must be much greater than the Earth; and in the last Lecture we shewed their Diameters were in Proportion, as 107 to 1.

295. Cor. 4. As the Earth's Shadow, where the Moon passes thro' it, is about three Times the Diameter of the Moon, it follows, that the Moon must be much less than the Earth;

296. Cor. 5. As the Earth's Shadow appears always circular on the Moon, it is an ocular Proof that the Earth is a Sphere or Globe, for otherwise its Shadow could not be always circular.

Of an ECLIPSE of the SUN.

297. An *Eclipse of the Sun* is caused by the Interposition of the Moon between the Sun and Earth, and thereby hiding the Sun, either in Whole, or in Part.

298. Of Solar Eclipses there are three Kinds, viz. *partial, total, and annular.*

A *partial Eclipse*, is when the Moon passes between the Spectator's Eye in such Manner, as only to hide a Part of the Sun. — When the Center of the Moon

is

is nearly in the same Direction as the Center of the Sun, if the Moon's apparent Magnitude be sufficient to hide all the Body of the Sun from the Spectator, such Eclipse is properly called *total*. But if the Moon is of less apparent Magnitude than the Sun, so that it only hides the middle Part of the Sun, leaving a Border or Ring of Light round it, the Eclipse is then said to be *annular*, which is a very rare Phenomenon.

299. Hence it appears, that what is commonly called an Eclipse of the Sun, is not strictly speaking a real Eclipse of the Sun: For the Sun being luminous in itself, cannot be deprived of its Light by the Interposition of any Body. Hence it is the Earth that is in Fact eclipsed, and not the Sun.

300. The Moon by its being interposed between the Sun and Earth, its Penumbra will eclipse some Parts of the Earth, and cause, in Appearance, an Eclipse of the Sun.

301. Hence it appears that an Eclipse of the Sun can only happen at new Moon, and not every new Moon, but only when the Moon is in Conjunction with the Sun near a Node, viz. within 18 Degrees.

302. An Eclipse of the Sun differs from an Eclipse of the Moon in the following Particulars.

1st. We have already observed, that an Eclipse of the Sun is only an Appearance; whereas, that of the Moon is really an Eclipse.

2d. An Eclipse of the Sun begins on the West Side of the Limb, and ends on the East: But an Eclipse

Eclipse of the Moon begins on the East Side, and ends on the West.

3d. Lunar Eclipses are more frequent to any particular Place of the Earth than Solar; notwithstanding, the Solar Limit is greater than the Lunar: Because, an Eclipse of the Moon appears the same from all Places of the Earth, as before observed; whereas, there may be at one Time a total Eclipse of the Sun at one Place, partial at another, and at other Places no Eclipse at all.

Transit of Mercury.

303. If the Orbit of Mercury lay in the Plane of the Ecliptic, at every inferior Conjunction it would transit the Sun, and appear like a black Spot thereon. — But as the Orbit is inclined about 7 Degrees, and intersects the Ecliptic in $14^{\circ} 43'$ of Taurus, and $14^{\circ} 43'$ of Scorpio, called the ascending and descending Nodes, a Transit can only be when the inferior Conjunction happens in, or near, these Parts of the Ecliptic, and so can only happen on or near the 6th of November, or 4th of May.

The last, which I calculated and observed, was on the 6th of May, 1753, at Bideford; it began before Sun-rise, but the End was at $9^{\text{h}} 55'$ apparent Time.

304. Hence Mercury has no Light in itself.

Transit

Transit of VENUS.

305. As the ascending Node of Venus is in 14 Degrees of Gemini, and its opposite or descending Node in 14 Degrees of Sagittarius, Venus can never transit the Sun, but when the inferior Conjunction happens on, or about, the 5th of June, or 6th of December.

306. The first Transit of Venus which was observed, was calculated and seen by Mr. *Jeremiah Horrox*, a young Gentleman near Liverpool, in the Year 1639; the next, I had the Pleasure of seeing at Bideford the 6th of June in the Morning, 1761; and as the Weather proved favourable of making a good Observation, the Emerfion began at 8^h, 2', 8'', which reduced to the Meridian of the Royal Observatory is 8^h, 16', 7''; and at Greenwich it was observed at 8^h, 19', 0''; and another will happen this Year 1769, on June 3d.

This Transit at the Earth's Center (London Time)

Begins at 7^h, 15', in the Evening.

Middle 10, 25, at Night.

End 1, 35, next Morning.

307. By Observations which will be made on this Transit, if the Weather proves favourable, it is hoped we shall be able to compute the Distances of the Planets from the Sun, more accurately than they are known at present.

A particular Account of this is given in the Lectures, but would take up too much room to be here inserted.

Of the SATELLITES of JUPITER.

308. The 4 Moons or Satellites of Jupiter, were discovered by *Galileo* in the Year 1610.

309. Their Distances from Jupiter and Periodical Revolutions are given in the Table annexed.

Satellite	Dist. in Semid. of $\mathcal{J}$	Periodic. Revolution D ^a
1	5.667	1 18 27
2	9.017	3 13 13
3	14.384	7 8 42
4	25.299	16 16 32

MOONS of JUPITER and SATURN.

310. Jupiter's Moons must, like ours, appear sometimes gibbous, full, &c.

311. As the Moon is eclipsed by the Shadow of the Earth, so are the Moons of Jupiter by the Shadow of that Planet.

312. It is evident, that as these Moons have different Periods, they must in different Nights appear to us very differently posited; sometimes most on one Side, sometimes on another, &c. And sometimes those which are really nearest to Jupiter's Body, will to us appear more remote.

of

Of the SATELLITES of SATURN.

313. The first who observed a Satellite of Saturn was Monsr. *Huygen*, who in the Year 1655 discovered one, viz. the fourth. As to the other four, they were discovered by *Cassini*.

314. Their Distances from Saturn and Periodical Times are as in the following Table,

Satellite	Distan. in Semidiamet. of the Ring	Periodical Time, D
1	2. 10	1 21 18
2	2. 69	2 17 41
3	3. 70	4 12 25
4	8. 70	15 22 41
5	25. 35	79 7 48

315. All these Satellites and their Eclipses, can only be seen by the Help of Telescopes, of very great magnifying Powers.

Their Phenomena are so nearly similar to those of Jupiter's Satellites, that nothing need be said on this Head.

LECT.

LECTURE IX.

Phænomenon of Saturn's Ring—Some of the modern Discoveries in Astronomy, particularly Sir ISAAC NEWTON's excellent System—Equation of Time—Precession of the Equinoxes—Phænomena of Comets, explained by a new Cometarium, &c.

316. SATURN's Ring is inclined to the Ecliptic about 30 Degrees, and is reckoned in Breadth about 21 thousand Miles.

317. The Ring goes through all its Appearances in about 14 Years.

318. Dr. Clark's Father, as Mr. Whiston says in his Memoirs of Dr. Clark's Life, saw a Star between the Ring and Body of the Planet.

319. It has long been discovered, that the Sun was not exactly in the Center of the several Orbits, though nearly so; and the sagacious Kepler found that the Orbits were really Ellipses, though very little different from Circles, and the Sun in their common Focus.

320. After Kepler came the most excellent Sir Isaac Newton. He has shewn that all Bodies have a Tendency towards each other; which he calls Gravity, or universal Attraction: He indeed does not take upon him to determine what it is, whether it is caused by any particular Natural Agent, or by the immediate Hand of the Deity; but evidently shews

the Existence of such a Thing; from whence he demonstrates,

321. 1st. That a Body being projected in the Direction of a right Line, and acted on continually by a Force tending to a Center, the Body or Planet so projected, must describe equal Areas in equal Times.

322. 2d. That every Body, that moves in a curve Line, described in a Plane, and by a Radius drawn to a Point, describes about that Point Areas proportional to the Times, is urged by a Force directed to that Point.

323. 3dly. It is demonstrated, that if a Body revolves in an Ellipsis, the Law of Centripetal Force tending to one of the Focus's, must be reciprocally as the Square of the Distance from the Focus; or Center of Attraction.

324. 4thly. And that a Circle, the attracting Power being in the Center, and an Ellipsis, the attracting Body being in one of the Focus's, are the only Curves that return into themselves, in which the Centripetal Force is in the inverse Ratio as the Square of the Distance.

325. For if the attracting Body was placed in the Center of the Ellipsis, the Law of Centripetal Force would be in the inverse Ratio of the Distance, and not of the Square of the Distance.

326. 5thly. That if several Bodies revolve about one common Center, with Centripetal Forces in the inverse Ratio of the Squares of the Distances; that then, the Squares of the periodic Times are as the Cubes of their Distances.

All

All these Propositions are strictly true, being mathematically demonstrated by the great Author in his *Principia*.

327. Now in the Heavens we observe these Phenomena.

Phœn. 1st. That the circumjovial Planets (or Satellites) by Radii drawn to Jupiter's Center, describe Areas proportional to the Times of Description; and that the Squares of the periodic Times are as the Cubes of their Distances.

328. Corollary. Hence it appears (by Prop. 2.) that they are urged by a Force directed to Jupiter; this Force, whatever it be, is what Sir *Isaac Newton* calls Attraction, or on our Earth, Gravity) and by 4th Proposition must move in circular or elliptical Orbits, having Jupiter in the Center of the Circle, or Focus of the Ellipsis. — The same is also true in Saturn's.

329. Phœn. 2. That the Squares of the periodical Times of the Earth, and other Planets about the Sun, are also as the Cubes of their Distances from the Sun.

330. Phœn. 3. That the primary Planets, by Radii drawn to the Earth, describe Areas no ways proportional to the Times: But that the Areas which they describe by Radii drawn to the Sun, are proportional to the Times of Description.

331. Phœn. 4. That the Moon by Radii drawn to the Earth, as a Center, describes Areas proportional to the Time. — Hence it is proved, that there is

such a Power as Gravity or universal Attraction, by which the Planets are retained in their Orbits: For from what has been just said, it appears, that the Planets have such a Tendency towards the Sun; the Moon to the Earth; the Satellites of Jupiter to Jupiter; and those of Saturn to Saturn.

332. With Regard to the Moon, it may be said, that we have an experimental Proof of such a Tendency to the Earth, which we call Gravitation. For the mean Radius of the Moon's Orbit being very nearly 60 Semidiameters of the Earth, if A C, Plate IIII. Fig. 2. represents a Part of her Orbit, described in one Minute, we can easily find B C equal to A D, how much the Moon must have fallen from the Line of Projection A B, to be in the Curve at C; and will be found very nearly equal to $15 \frac{1}{2}$ Paris Feet; the Space that the Moon would fall in the first Minute; if she was let drop towards the Earth.— Now, as the Power of Gravity decreases as the Square of the Distance increases, at the Distance of the Moon or 60 Semidiameters from the Earth, it can only be $\frac{1}{60}$ multiplied by $\frac{1}{60}$, or $\frac{1}{3600}$ of the Power at the Earth's Surface: But at the Surface of the Earth it is known by Experiment, that falling Bodies describe $15 \frac{1}{2}$ Paris Feet in the first Second or 54300 Feet per Minute; therefore, at the Distance of the Moon, can only fall $\frac{1}{3600}$ of 54300, or $15 \frac{1}{2}$ Feet; which is the same as is shewn above that the Moon really falls, to revolve in its Orbit. And since it now appears, that a heavy Body at the Distance

of the Moon, would deſcend towards the Earth with the ſame Velocity as the Moon actually does, have we not the ſtrongeſt Proof the Nature of the Thing can admit of, that the Moon is a heavy Body, acted on by ſuch a Power as we call Gravity?

333. Hence Sir *Iſaac Newton's* System cannot with Propriety be called an Hypotheſis, ſince ſuch a Power, as he calls Gravity or Attraction, really exiſts in the Heavens, and obſerves the ſame Laws as his Gravity.

334. From this only, he elegantly (and he only ſeems to have had a Capacity and Induſtry equal to it) accounts for all the little Irregularities in the Motion of the Moon, which had before baffled the united Labours of the learned World: But now, by more minutely taking into Conſideration the mutual Gravitation of the Planets towards each other, we are enabled to compute Tables of her Motions to ſuch an Accuracy, as was before too much for Hope to wiſh.

335. And after all this, is it not ſtrange to ſee, that ſome Perſons, who are not capable of reading the excellent *Principia*, and conſequently not able to judge of the Force of his Reasoning, take upon them to decry the Writings of this great Man, of which we have lately had ſeveral Inſtances?

Of EQUATION of TIME.

336. In order to account for this, let us firſt obſerve, that ſince the Earth revolves in an Ellipſis,

the Sun being in the Focus, it is at different Times at different Distances from the Sun; and, as by what has been just shewn, describes equal Areas in equal Times; it must move with different Velocities in different Parts of its Orbit; sometimes faster, sometimes slower; this is very sensible, for the Sun is about eight Days longer describing the Northern Part of the Ecliptic than the Southern; and therefore, on this Account, the Clocks which are constructed to keep equal Time, cannot agree with the Time by the Sun. This Inequality is one Part of the Equation of Time. — But there is another Part owing to the Sun's moving in the Ecliptic, and not in the Equinoctial.

Hence it appears that the Sun must be sometimes faster, sometimes slower than the Clocks, or equable Time, on two Accounts; which being combined together, form the Equation of Time, given in our common Almanacks:

The greatest Equation is a little more than 16'.

Of the PRECESSION of the EQUINOX.

337. Every one may observe, that on the Celestial Globe, the Constellations are now laid down, almost a whole Sign forward from the Points of the Ecliptic bearing their Names, and that they apparently move forward about 50'' of Longitude each Year, which is caused by the Earth's Axis not keeping exactly a Parallelism, for tho' we suppose it to be so, in accounting for the Seasons, as the annual Difference

ence

rence we are now speaking of, is too inconsiderable to affect that Phenomenon; yet by comparing together the Observations of many distant Years, we find, that the Axis of the Earth has not exactly kept its Parallelism, but deviated from it so, that the Axis of the Earth which at any Time points at any Place in the Heavens, will in 72 Years point at another Place one Degree to the West, or backward, and so would compleat its conical Revolution in 25920 Years.

338. Hence the Solstitial Points move backwards one Degree in 72 Years, and consequently the Equinoctial Points, or Intersection of the Ecliptic and Equator, which are always 90° distant from the Solstices, will also move as much backward; consequently, if we represent the Equinoctial Points γ and α as fixed Points, as they are on common Globes, the Constellations must be placed forward, in order of the Signs.

339. As to the Physical Cause, none before Sir ISAAC could so much as guess at it; but he has elegantly shewn it to arise from the Attraction of the Sun and Moon, on the oblate spheroidical Figure of the Earth: And that the annual Precession of the Equinoxes arising from the Force of the Sun, is $9'' 7'' 20'''$; from the Moon $40'' 52''' 52''''$; the Sum of both $50'' 0''' 12''''$; the Quantity of which Motion agrees accurately with Observations, it being found by the most celebrated Astronomers to be $50''$.

What

What an astonishing Genius had this Man! Well might *Pope* write,
 "GOD said let *Newton* be, and all was Light."

OF COMETS.

340. By the Observations of modern Astronomers, the Comets seem to move in Elliptic Orbits, and to be governed by the same Laws as the Motions of the Planets: Only in Orbits more excentric. — Hence it follows, that in such Case, the Comets must have regular Periodical Returns like the Planets: But the Misfortune is, that most of the ancient Astronomers, and Astrologers, imagined Comets to be only Meteors, and fatal Presages of some great Evil to follow; and for that Reason never took any exact Astronomical Observations of their Motions; thinking it sufficient to say, that at such a Time, a Comet of such a Magnitude appeared in such a Constellation of the Heavens, and after it such direful Events happened. For which Reason, as the periodical Returns of Comets consist of a large Number of Years, the Periods of very few have been determined. The first Comet which hath been observed, with a necessary Degree of Accuracy, was that of the Year 1577, by *Tycho Brahe*.

341. The learned *Dr. Halley* in his Synopsis of the Astronomy of Comets, says, "There are many Things which make me believe that the Comet which *Apian* observed in the Year 1531, is the same
 with

with that which *Keplar* and *Longomontanous* more accurately described in the Year 1607; and which I myself have seen return, and observed in the Year 1682. All the Elements agree, and nothing seems to contradict this my Opinion besides the Inequality of the periodic Revolutions. Which Inequality is not so great neither, as that it may not be owing to Physical Causes. For the Motion of Saturn is so disturbed by the rest of the Planets, especially by Jupiter, that the periodic Time of that Planet is uncertain for some whole Days together. — How much more therefore will a Comet be subject to such like Errors, which raises almost four Times higher than Saturn, and whose Velocity, tho' increased but a very little, would be sufficient to change its Orbit to a parabolical one." He also remarks its being seen in the Year 1456; and the same Comet (as he thinks) was seen in the Year 1305, which is another double Period of 151 Years. Hence he ventured to foretell that it would return again in 1758; and it did actually return in the Beginning of the Year 1759, at which Time it was visible in many Parts of America; and observed to be, as Mr. Turner says, ascending back from the Center of the System.

Another Comet was observed in 1661, and is supposed will return again in about 575 Years, or about the Year 2255.

These are all whose Periods are as yet known.

342. The Number of Comets which have been observed are about 40.

343. The

343. The Nature of a Comet's Path was not known before Sir *Isaac Newton* applied himself to the Subject.

344. From the Motion of Comets it is evident the Celestial Spaces are void of Resistance. For though the Comets are carried in oblique Paths, and sometimes contrary to the Course of the Planets, yet they move every Way with the greatest Freedom, and preserve their Motions an exceeding long Time, even where contrary to the Course of the Planets. — Hence the *Cartesian* Doctrine of Vortices to carry the Planets round the Sun, is absurd.

345. The Opinion of some Writers that Comets are only Meteors, who have been led into this Opinion by the Changes that happened to their Heads, is without Foundation. For the Heads of Comets are encompassed with huge Atmospheres, and the lowermost Parts of these Atmospheres must be densest: And therefore it is in the Clouds only, and not in the Bodies of the Comets themselves that these Changes are seen. Thus also the Belts of Jupiter, as Sir *Isaac Newton* observes, are formed in the Clouds of that Planet.

346. Sir *Isaac Newton* computes, that the Comet of 1680, when in its Perihelion, must be heated by the Sun 2000 Times hotter than red-hot Iron. Hence it follows, that the Bodies of Comets must be very solid, compact, fixt and durable, like the Bodies of the Planets, otherwise their Particles of Matter would fly off.

The

The greatest and most fulgent Tails always arise from Comets immediately after their passing by the Neighbourhood of the Sun. Therefore, the Heat received by the Comet conduces to the Greatness of the Tail. Hence we may infer, that the Tail is nothing but a very fine Vapour, which the Head, or Nucleus of the Comet, emits by its Heat.

We cannot end this * first Part of our Lectures better, than observing, " That this most beautiful System, could only proceed from the Council and Dominion of an intelligent, powerful, wise, and good Being, whom we call GOD.

I.

The spacious Firmament on high,
With all the blue etherial Sky,
And spangled Heavens, a shining Frame,
Their great Original proclaim :
Th' unwearied Sun, from Day to Day,
Does his Creator's Pow'r display,
And publishes to every Land
The Works of an Almighty Hand.

II.

Soon as the Ev'ning Shades prevail,
The Moon takes up the wondrous Tale,

And

* When for Conveniency, in the Academy, our Lectures are parted into two Divisions, we generally stop here. — But when it is intended to read one continued Course, after Mechanics we proceed to the Lectures on *Hydrostatics*, *Pneumatics*, *Electricity*, and *Optics*, in order to conclude with the sublime Science of *Astronomy*.

And nightly to the listning Earth
 Repeats the Story of her Birth:
 Whilst all the Stars that round her burn,
 And all the Planets in their Turn,
 Confirm the Tidings as they roll,
 And spread the Truth from Pole to Pole.

III.

What though, in solemn silence, all
 Move round the dark terrestrial Ball?
 What tho' nor real Voice nor Sound,
 Amid their radiant Orbs be found?
 In Reason's Ear they all rejoice,
 And utter forth a glorious Voice,
 For ever singing, as they shine,
 "The Hand that made us is divine."

Spectator, Vol. VI. No. 465.



SUPPLEMENT

TO

LECTURE II.

Of the ATTRACTION *of* MAGNETISM.

THE principal Properties of the Magnet or Load-stone are,

1st. A Magnet which can move freely in an horizontal Position, will always turn one of its Ends towards the North, the other towards the South. Hence these Ends are called its Poles. *Exp.*

2d. This Virtue is communicated to, or rather excited in Iron by the Touch. *Exp.*

3d. Either Pole of a Magnet will attract Iron. *Ex.*

4th. When Needles are touched for Compasses, that Point which was touched with the South Pole of the Magnet will point Northward; and the other End Southward. *Exp.*

5th. The Poles of a Magnet of different Denominations attract, but those of the same Name repel each other. *Exp.*

6th. That there is such a Power as Attraction and Repulsion in Magnets. *Exp.*

7th. The Compass Needle does not point exactly the same in every Place, or in the same Place at different Times.

In some Places its North Point stands some Degrees to the Eastward of the North, in some to the Westward.

This Deviation is called the *Variation*, and is said to have been first discovered by *Gonzales Oviedo* and *Sebastian Cabot*.

At London in the Year 1580 it was found to be $11^{\circ} 15'$ East; but is now about 21 Degrees West.

8th. Needles which would hang in an horizontal Position, before touching, will when touched dip below the horizontal Line.

9th. The Magnetic Virtue may be destroyed or restored. *Exp.*

10th. This Virtue may be communicated to Iron by a strong Attrition all one Way.

11th. Iron Bars acquire a Magnetic Virtue by standing long in one Position.

12. Artificial Magnets are easily made by properly touching of Steel Bars. *Exp.*

The End of the FIRST PART.



A COURSE



A
C O U R S E

OF
Experimental Philosophy.

PART II.

CONTAINING
HYDROSTATICS, HYDRAULICS, THEORY of the
TIDES, PNEUMATICS, ELECTRICITY, and OPTICS.

LECTURE X.

HYDROSTATICS.

Of the Equilibrium and Pressure of Fluids in general.

347. **H**YDROSTATICS is the Science which considers the Equilibrium and Pressure of Fluids in general.

348. A *Fluid* is a Body that yields to any impressed Force, and whose Parts by yielding, are easily separated from one another.

L 2

349. The

349. The minute Particles of Fluids, do not seem to differ from those of solid Bodies.

For Fluids and Solids are frequently changed into each other; e. g. Water into Ice by Cold, and again to Water by Heat; Metals of all Kinds, being melted, become fluid; and cooling, grow solid again, &c.

350. Fluids as well as Solids, it is well known, consist of heavy Particles, whose Gravity is always in Proportion to the Quantity of Matter they contain. Which, as far as Experience reaches, appears to be the universal Property of all Matter, whatever be its Figure.

351. A *Liquid* is a Fluid, which acquires a Surface parallel to the Horizon, or rather to the Surface of the Earth, and has the peculiar Quality of wetting most Bodies immersed in it, arising from the Adhesion of its Particles to the Surface of the Body immersed, as Water, Spirits, Oils, &c.

352. These are Properties not common to all Fluids, as may be seen in a Flame or Smoke, &c. which being specifically lighter than Air, will ascend.

353. It is probable that the Parts of Fluids are of a spherical Figure, as Bodies of that Form are more easily moved over each other, and as they can only touch one another in a Point, they cannot adhere together so strongly by the Attraction of Cohesion, as if they were of a different Figure.

This indeed in some Degree admits of ocular Proof, For the greatest Parts of all Fluids may by the

the Help of Microscopes, be observed to have this Figure. And even without Microscopes in Drops of Water or Quicksilver let fall from a Finger.

Air always puts on this Form.—Smoke of Coals received on a plain Superficies, and viewed by a Microscope, Dr. *Muschenbrock* says, exhibit nothing but mere Globules; and Dr. *Derham* has observed the Vapours in a dark Room to be spherical. And If this appears in Fluids of grosser Parts, may we not conclude by Analogy, that they are so likewise in Fluids of more subtle Parts?

354. That the Particles of Fluids are very subtle or minute, is manifest from their easily penetrating thro' the Pores of other Bodies; thus, Air is found to pass through all Kinds of Wood; Water into all Kinds of Vegetables; the Light thro' Glass, &c.

355. Some Fluids are very compressible as *Air*; and others admit of very little Compression, as *Water*; which may almost be looked upon as incompressible. For hollow Globes of Metal have been filled with Water, and then have been hammer'd and squeez'd in strong Presses to alter the Shape of the Vessel; and as into what ever Figure it was altered it must have a less Capacity, the Water must be proportionally compressed; but when ever the Shape of the Globe was altered, the Water ouzed thro' the Pores of the Metal.—Hence it appears, that Water may in Practice be looked upon as incompressible. And that the Particles of Water are less than the Pores of Metal, even of Gold; for

it has been found that the Water passed in a Sort of Dew thro' a Sphere of Gold.

356. Though by Hydrostatics, as before observed, we commonly understand the Doctrine of the Equilibrium, and Pressure of Fluids in general; yet the Word seems according to its Etymology *ὕδωρ* Water, and *σταλιν* Weight, to be confined to Water; a particular Fluid, and the most simple of all; and which we shall chiefly make use of in our Experiments, and the Deductions must be as conclusive, as if various Liquors were made Use of: For whatever can be proved by Experiment and true Reasoning, to belong to any one Body which is both fluid and heavy, upon Account of its Weight and Fluidity, must certainly belong to all others, which are fluid and heavy.

357. We shall now proceed to shew experimentally the Truth of the most valuable Hydrostatic Propositions. But first must observe, that in order the more readily to demonstrate and explain the principal Phænomena in Hydrostatics, we suppose a Fluid contained in a Vessel to be cut into several horizontal Planes or imaginary Surfaces.

358. We are likewise to conceive the whole Fluid contained in a Vessel, to be divided into perpendicular Columns from the Top to the Bottom of the Fluid, either round, prismatic, or of any other Figure, according to the Shape of the Surface of the Bodies pressed on, under Water; viz. a cylindric Column, if pressing a round Body; a triangular, if pressing

pressing a Triangle; and a Square, if on a Square Body, &c.

359. Hence it appears, that each Body is pressed by a Weight equal to the Weight of the Column of Water over it; and the different Surfaces are pressed by Weights proportional to the Area of the Surface into the perpendicular Height of the Column: For these Products being the Contents of the Columns, or expressing the proportional Quantities of Water, their Weight or Pressure must be in the same Proportion.

360. Prop. That Fluids gravitate in *Proprio loco*, as the Philosophers express themselves; that is, are heavy at all Times, and in any Situation.

Solution. Since the whole Weight of every Fluid, as well as solid, must be made up of the Weights of the several Parts, it is manifest, I think, that the Parts do therefore gravitate in the Whole, or in *Proprio loco*.

This seems so clear, that I should not have taken any Notice of it, had not some Philosophers brought Experiments in support of the Contrary.

In the Lectures, these Objections are removed, and the Proposition proved by Experiment.

361. Fluids press every Way, and in all Directions. *Exp.*

362. That the Pressure upwards is equal to the Pressure downwards. *Exp.*

363. That the upper Pressure will support Lead, or the heaviest of Metals, viz. Gold from sinking in Water. *Exp.*

That

364. That light Wood will not swim, if the upper Pressure be taken off. *Exp.*

365. That the lateral Pressure of Fluids is equal to the perpendicular Pressure downwards. *Exp.*

366. That the Pressure of Fluids is proportional to the Height of the Fluid only, without any Regard to the Quantity thereof.—This is commonly called the Hydrostatic Paradox. *Exp.*

367. Corollary. Hence it follows that Vessels of equal Bases and Heights, whatever Difference there is in their Figures or Contents, will have equal Pressure on their Bases.

368. If Water in different Receptacles, as Lakes, Ponds, Wells, or Vessels, of any Kind whatsoever, communicate with each other, they will stand at the same Height. *Exp.*

369. Hence, we have the Water level, of use in conducting Water from one Place to another.

370. In Levelling, set all the Heights observed backwards in one Column, and those observed forwards in another; then subtract the least Sum of all the Heights from the greater, the Remainder will be the Difference between the Heights required, of the two Places.

371. If the Sum of all the forward Heights, exceed the Sum of all those backward, the first Place is the Highest.

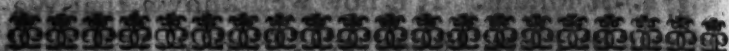
N. B. If the Distance is considerable, a small Correction must be made for the Curvature of the Earth.

Scholium.

372. Scholium. It is now well known, that Water may by Pipes, be conveyed from one Hill down a Vale and up another, &c. to any Distance; yet the ancient *Romans* were certainly ignorant of this; otherwise they would not have been at the immense Expence of building Aqueducts from one hill to another, over Arches or Kinds of Bridges built one over another; as may be seen in several Places.—And we never find any of their Pipes for conveying of Water, rise again after once descending.

373. The Pressure of Water against any Surface is equal to the Content of a Body of Water whose Base is the Surface pressed, and Height the Distance of the Center of Gravity of that Surface, from the Surface of the Water.





LECTURE XI.

HYDROSTATICS *continued.*

Of the Specific Gravity of Liquids and Solids.—Swimming and Sinking accounted for.—Common Method of finding Tonnage of Ships very false, and true Way pointed out.—To find the solid Content of any irregular Piece of Wood, Stone, &c.—To discover bad Money.—Cause of the Tides of the Ocean.—Running of Syphons, Tantalus Cup.—Reciprocating Springs.—Antigugler, Funnel or Fountain of Command.—Jet d'Eau, or common Fountain.—Velocity of Water running thro' Holes in the Sides or Bottoms of Vessels.

374. **S**PECIFIC Gravity is a comparative Term, and denotes the Proportion, Gravities or Weights between different Bodies of the same Magnitude.—Thus, if two Bodies of equal Magnitudes weigh 3lb. and 6lb. their Specific Gravities are said to be as 1 to 2.

375. If a Body be immersed in a Liquid it will remain in Equilibrium, swim or sink, according as its specific Gravity is equal, less, or greater, than that of the Fluid. *Exp.*

376. That a Body swimming in Water, as for Instance a Ship, will be immersed to such a Depth, as that the Weight of a Quantity of Water, equal in Bulk

Bulk to the Part of the Ship immerſed, ſhall be equal to the Weight of the whole Ship and Materials. *Ex.*

377. A Ship will ſwim as boyant in a Dock, as in the open River. *Exp.*

378. Corollary. Hence it is poſſible for a Ton or two of Water to lift a Ship of 1000 Tons.

379. On the Principle of Art. 376, it is not difficult to find the Tonnage of Ships on a true Principle; whereas that commonly practiſed is abſurd; making two Ships, provided they have the ſame Length of Keel and Breadth of Beam, to have the ſame Tonnage, though one may be built very ſharp, the other very full.

380. Since a Body totally immerſed in Water diſplaces as much Water as is equal in Bulk to the Solid immerſed, it is eaſy by this Means to meaſure or find the ſolid Content of any Body, however irregular its Figure may be. — Illustrated by *Exp.*

381. A Body weighed in a Fluid lighter than itſelf, loſes a Part of its Weight, equal to the Weight of ſo much of the Fluid as would fill its Place. *Exp.*

To find the ſpecific Gravity of FLUIDS.

382. From the laſt Propoſition it follows, if one and the ſame Solid be immerſed in different Fluids, the Weight which it loſes in them will expreſs their ſpecific Gravities.—The Weight of it in each Liquor, expreſſing the Weight of an equal Bulk (to the Solid) of the Liquid.

Thus

Thus it is found that a Cubic Inch of Brass loses $253 \frac{1}{3}$ Grains of its aerial Weight in Water; in Proof Spirits 235 Grains.

Hence a Cubic Inch of Water weighs $253 \frac{1}{3}$ Grains. A Cubic Inch of Proof Spirit 235 Grains. And therefore their specific Gravities are as $253 \frac{1}{3}$ to 235. Or which is better expressed, as 1006 to 928.

383. To find the specific Gravities of Solids heavier than the Fluid in which they are weighed.

This is done by weighing them severally in a Fluid lighter than themselves, the Weight which each Solid loses being to its Weight in Air as the specific Gravity of the Fluid, (Water 1000) to the specific Gravity of the Solid.

N. B. If a Guinea, weighing 129 Grains, loses $7 \frac{1}{4}$ Grains, we have, as 7.25 is to 129 so is 1000 to 17793, which is the true Standard. Or 129 divided by 7.25 gives how much a Guinea is heavier than Water, viz. 17.793 Times.

384. To find the specific Gravities of Solids lighter than the Fluid.

Amongst other Methods is the following; since a Body swimming must displace as much Water as is equal in Weight to the swimming solid; if a Glass Vessel be filled full of Water, and then the Solid be put to swim on the Surface of the Water, it will force as much Water over the Brim into the other Vessel, as will be equal in Weight to the Solid.

By this Principle the well known Story of the Crown of King Hiero of Syracuse may be illustrated,

ed, but would take up more Room than we can conveniently spare in this Epitome.

385. A TABLE of the specific GRAVITY of BODIES.

Fine Gold	—	19. 640	Oil of Tartar	—	1. 550
Standard Gold	—	18. 888	Bezoar	—	1. 500
Quickfilver	—	14. 000	Honey	—	1. 450
Lead	—	11. 325	Gum Arabick	—	1. 375
Fine Silver	—	11. 091	Spirit of Nitre	—	1. 315
Standard Silver	--	10. 535	Aqua Fortis	—	1. 300
Bismuth	—	9. 700	Pitch	—	1. 150
Copper	—	9. 000	Spirit of Salt	—	1. 130
Cast Brass	—	8. 000	Craftsmen of human	}	1. 126
Steel	—	7. 850	Blood		
Iron	—	7. 645	Spirit of Urine	—	1. 120
Tin	—	7. 320	Human Blood	—	1. 054
Glass of Antimony	--	5. 280	Amber	—	1. 040
A Pseudo Topaz	--	4. 270	Serum of human Blood	—	1. 030
A Diamond	—	3. 400	Milk	—	1. 030
Clear Chrystal Glass	-	3. 150	Urine	—	1. 030
Iceland Chrystal	—	2. 720	Dry Box-Wood	—	1. 030
Fine Marble	—	2. 700	Sea Water	—	1. 030
Rock Chrystal	—	2. 650	Common Water	—	1. 000
Common Green Glass	—	2. 620	Camphire	—	0. 996
Stone of a mean Gravity	—	2. 500	Bees-Wax	—	0. 955
Sal Gemme	—	2. 143	Linseed Oil	—	0. 932
Brick	—	2. 000	Dry Oak	—	0. 925
Nitre	—	1. 900	Oil Olive	—	0. 913
Alabaster	—	1. 875	Spirit of Turpentine	—	0. 874
Dry Ivory	—	1. 825	Rectified Spirit of Wine	—	0. 866
Brimstone	—	1. 800	Dry Ash	—	0. 800
Dantzick Vitriol	—	1. 715	Dry Maple	—	0. 755
Allum	—	1. 714	Dry Elm	—	0. 600
Borax	—	1. 714	Dry Fir	—	0. 550
Calculus Humanus	--	1. 700	Cork	—	0. 240
Oil of Vitriol	--	1. 700	Air	—	0. 001

386. The specific Gravity of different Fluids may also be found without weighing. Illustrated by shewing Quickfilver to be 14 Times heavier than Water.

Of the TIDES of the OCEAN.

387. The Tides are caused by the Attraction of the Sun and Moon.

388. At new and full Moon the Attractions of the Sun and Moon act together to raise the Tide, and thereby the Spring or highest Tides are produced.

But when the Moon is in the Quadratures, the Sun endeavours, if I may so speak, to raise the Tide at one Place, and the Moon at a Place 90° distant, and consequently the Tide cannot be so high at the Place under the Moon as when the Sun and Moon act together.—This is the Cause of our neap Tides.

389. It ought here to be remarked, that as the hottest Time of the Day is not exactly when the Sun is in the Meridian, or exactly at Noon, but some time after, viz. between 1 and 2; and the hottest Time of the Year is not at Midsummer when the Sun enters Cancer, but about July or August, and the like of coldest Weather, being not in December but about January or February; so in like Manner the highest Tide is not exactly at new or full Moon but some Tides after; the lowest Tide, some Tides after the Moon quarters.

390. As the Moon is so near the Earth, her attractive Force to cause the Tides is greater than that of the Sun; and hence it is easily observed by every Person, that the Tides seem to be governed by the Moon.—As to our having two Tides a Day, it is
owing

owing to the Moon's coming twice to the Meridian of any particular Place in a Day, * viz. once on the South and once on the North, by the Rotation of the Earth round its Axis every Day.

391. The Tide is highest not when the Moon is on the Meridian but some Hours after.

To treat of this curious Subject fully, would take up more Room than is consistent with the predetermined Bulk of this Work. We must therefore either refer those who are desirous of seeing more on this Subject, to our Lectures, or to Dr. *Halley's* Account, grounded on Sir *Isaac Newton's* Principia.

392. The specific Gravities of Liquids may also be readily found by an Hydrometer. — This is commonly used for trying the Strength of Spirituous Liquors. For if pure Spirit of Wine be mixed with an equal Quantity of Water, it makes what is called Proof Spirit. If then a Weight be added to make this Instrument sink in Proof Spirit to the middle Point, or tenth Division of the Stem, if it be put into any weaker Spirit it will not sink so deep, and into stronger will sink deeper. — This is generally made of Ivory, Glass, or Copper.

H Y D R A U L I C S.

Of the Running of SYPHONS.

393. Syphons are of such common Use in decanting of Liquors as to need no particular Description.

M 2.

The

* Or rather in about 25 Hours..

The Leg of the Syphon, thro' which the Liquid is to be discharged, must be longer than that in the Liquid; then the Syphon being filled with the Liquid by sucking or otherwise, it will run out by the Excess of the Weight of the Liquid in one Leg more than in the other.

Of the TANTALUS CUP.

394. This is a Cup in which a Syphon is concealed, and when the Liquor comes to a proper Height will empty itself.

Hence may be illustrated the Nature of *Intermitting Springs*, which being supplied by a Syphon can only act when that works.

Hence also the Nature of *Reciprocating Springs*, or Springs which alternately ebb and flow; a remarkable Instance of which is *Laywell* at Brixham, near Tor-Bay, in Devonshire.—*Exp.*

395. Experiments with the Antigugler, Funnel or Fountain of Command, and common Fountain.

396. The Velocity of Water spouting through equal Holes, is as the Square Root of the Height of the Water above the Holes.—*Exp.*

397. As to Pumps, which are generally given in Hydrostatic Lectures, we shall explain the Manner of their Operation in our next Lecture, being properly Pneumatic Engines, the Water being forced up in them by the Pressure of the Atmosphere.



LECTURE XII.

PNEUMATICS.

That Air is a heavy Body.—That the Quicksilver in the Barometer or common Weather Glass is sustained by the Pressure of the Atmosphere.—That the Pressure of the Atmosphere on every square Inch is equal to about 15 Pounds Weight.—That our Bodies are pressed by a Force of about 13 Tons.—Rules to judge of the Weather by the Barometer.—Of several Sorts of Pumps.—A Shower of Quick-silver through the Pores of Wood.—Artificial Fountain, &c.

398. **H**AVING considered the Nature of Fluids in general, we now proceed to the Properties of some particular Fluids.

And 1st of the Air.

399. The Air is a fluid transparent Body, capable of being condensed and dilated; which surrounds our Earth to a considerable Height; And this whole Quantity is commonly called the Atmosphere.

400. It will be proved in these Lectures,

First. That the Air is a heavy Body.

Second. And resists the Motion of Bodies.

Third. That it has a Springiness or Elasticity,

That AIR is a heavy Body.

401. The Pressure or Weight of the Air may be proved by a Number of Experiments: Some of which are,

First. By pressing down the Hand on an open Glass, so that the Hand cannot be easily removed, without turning the Cock of the Air Pump to let in some Air into the Glass, to balance by its upper Pressure, the Weight or Pressure of the external Air; and then the Hand immediately becomes disengaged.

402. *Exp. 2d*, By pressing down a Receiver placed over the Hole of the Pump.

403. *Exp. 3.* To shew that this is not owing to any Suction of the Pump, but to a real Pressure of the Air.

Of the BAROMETER.

404. *Exp. 4.* That the Column of Quicksilver in the Barometer is sustained by the Pressure of the Atmosphere.

405. Corollary. From this Experiment it appears, that at a mean State of the Atmosphere, its Pressure on the Surface of the Earth is equal in Weight to the Pressure of the Weight of $29 \frac{1}{2}$ Inches Depth of Quicksilver all over the Earth. Now a square Column of Quicksilver $29 \frac{1}{2}$ Inches high and one Inch thick, weighs just 15 Pounds, which is therefore equal to the Pressure of the Atmosphere on every square Inch on the Earth's Surface; and 144 Times

as much, or 144 multiplied by 15 equal to 2160 Pounds, upon every square Foot. And therefore, the Surface of a middle ſized Man being about 14 ſquare Feet, ſuch a Perſon muſt be preſſed with a Weight of 2160 Pounds multiplied by 14, or 30240 Pounds, i. e. about $13\frac{1}{2}$ Tons; a Weight which would cruſh us to Pieces, was it not for the Spring of the Air which is internally in every Part of our Bodies, &c. and the Spring of the Air, being always equal to its Weight, (as will be ſhewn in ſome of our Experiments) counterbalances the Preſſure of the external Air, and ſo is not perceived by us.

406. The principal Obſervations which have been made on the Barometer, as drawn up by Dr. Halley, are.

1ſt. That in calm Weather, when the Air is inclined to Rain, the Mercury is commonly low.

2. That in ſerene, good, ſettled Weather the Mercury is generally high.

3. That upon very great Winds, though they be not accompanied with Rain the Mercury ſinks loweſt of all, with relation to the Point of the Compaſs the Wind blows from.

4. That *cæteris paribus*, the greateſt Heights of the Mercury are found upon Eaſterly and North-Eaſterly Winds.

5. That in calm froſty Weather the Mercury generally ſtands high.

6. That after very great Storms of Wind, when the Quickſilver has been low, it generally riſes again very faſt.

7. That

7. That the more Northerly Places have greater Alterations of the Baroscope than the more Southerly.

8. That within the Tropics and near them, those Accounts we have had from others, and my own Observations at St. Helena, make very little or no Variation of the Height of the Mercury in all Weathers.

OF PUMPS.

407. To the Weight of the Air is owing the Operation of the common Pump; commonly called the Sucking Pump.

When the Piston descends, the Air contained between the upper and lower Box is in some degree condensed, and by its elastic Force presses down the Valve of the under, and forces open the Valve of the upper Box (viz. that fixed to the Piston). Then, rising the Piston, the Weight of the Atmosphere shuts the Valve of the upper Box, and so the Pressure of the Atmosphere being as it were lifted up, the little Air remaining between the upper and lower Box will have a larger Space to expand itself in, and consequently its Pressure on the Valve of the lower Box will be inconsiderable, and not able to resist the Water in the Well, being forced up by the Pressure of the Atmosphere. Then on the Return of the Piston its Valve opens again, and being again raised, its Valve shuts, and consequently, as much Water as was above it, will be raised up, by the Piston, &c.—Exp.

408. Hence

408. Hence appears the Reason why the common Pump can raiſe Water no higher than about 33 Feet; for Quickſilver being about 14 Times heavier than Water, the Atmosphere can ſuſtain a Column of Water 14 Times higher than Quickſilver; now $29\frac{1}{2}$ Inches multiplied by 14 is equal 413 Inches, or 34 Feet 5 Inches; but, as it is impoſſible perfectly to exhauſt the Air, the Pumps cannot perform above 32 Feet, or there about, in Height.

Of the FORCING PUMP.

409. The Piſton of this Pump is a ſolid Cylinder, and to the Barrel of the Pump is fixed a Pipe, called the Forcing Pipe, to convey the Water up to a Ciſtern or Reſervoir.

When the Piſton riſes, the Air is rarified above the Valve of the Pump, and then the Water riſes by the Preſſure of the Atmosphere, as in the common Pump: But at the Return of the Piſton, as the Valve in the Barrel ſhuts, and the Piſton is ſolid, the Water can go no Way but up the Forcing Pipe.

410. To this Pump it is common to fix an Air Barrel, in which, when the Air is condensed, by its Spring it acts upon the Water to force it up the Pipe, and ſo renders the Stream more conſtant — *Ex.*

411. The common Engine for extinguishing Fires called *Newſham's* Fire Engine, is only a Machine with an Air Veſſel and two ſuch Pumps, to render the Stream without Intermiſſion.

412. The

412. The Pressure of the Air may also be proved by the great Force required to pull asunder two Brass Hemispheres when the Air is exhausted.—*Exp.*

413. By weighing the Air in a Florence Flask:—*Exp.*

Exhaust the Air out of the Flask, which may be done by putting it under a Receiver, or, easier, by a little Brass Pump.—Then hanging it on one End of a Balance equipoise it with Weights in the Scale. And letting in the Air by lifting up the Bladder Valve, the Flask will preponderate, and the Number of Grains we must put in to restore the Equilibrium, will shew the Weight of a Bulk of Air equal to the Capacity of the Flask. Now my Flask contains about a Pint; and the Air in it weighs about 9 Grains, therefore a Gallon of such Air will weigh three Pennyweight.—*Exp.*

414. By forcing Water into a hollow Ball of Glass. Exhaust the Air; then letting in the Air it will press on the Water in the Bason, and force it up into the Ball.—The Bubble cannot be filled with Water, because the Air cannot be entirely exhausted.—*Exp.*

415. By its forcing Quicksilver thro' the Pores of Wood like a Silver Shower.—*Exp.*

416. By its breaking a Bladder on an exhausted Glass.—*Exp.*

417. By an artificial Fountain.—*Exp.*

418. That Air by its Weight will pass thro' the longitudinal Vessels of Wood, but will not pass thro' transversely.—*Exp.*

Let

Let one End of the Wood be immersed in Water. Then, on exhausting the Air out of the Receiver, you will see Air come in thro' the Stick to the Water; but, stopping the Pores of the upper End of the Stick with your Finger, you cannot perceive any Air to enter thro' the Wood into the Water.

LECTURE XIII.

PNEUMATICS *continued.*

That Air resists Bodies in Motion.—Is elastic —Sound cannot be produced without Air.—Air capable of being rarified and condensed, &c.

419. **T**HAT Air resists Bodies in Motion. This appears by the Experiment of the Guinea and Feather. For every Person knows, that if a Guinea and Feather be let fall in open Air, the Guinea will fall much faster than the Feather, being less resisted by the Air, as its specific Gravity is much greater than that of the Feather. But if they are both let fall from the same Heighth in an exhausted Receiver, the Resistance of the Air being then taken off, they will both fall together.

420. Second. By the Philosopher's Hammer. *Ex.*

421. The Spring of the Air may be proved by a Number of Experiments, some of which are,

By

By a Bladder almost empty of Air, expanding itself in an exhausted Receiver, so as to appear full blown, by the Spring of the internal Air.—*Exp.*

422. By the same Bladder raising a Weight by the Spring of its internal Air, when the Air is exhausted out of the Receiver.—*Exp.*

423. By forcing Water out of a Glass Bubble. *Ex.*

424. By the Lungs Glass; shewing how the Lungs are affected for want of Air to expand them.—*Exp.*

As it is not agreeable to punish Animals unnecessarily, this is contrived to shew how they die for want of Air, or, which is the same in Effect, when the Air by Damps, as in Mines, &c. has lost its Elasticity or Springiness.

Thus the Lungs of an Animal in Vacuo are pressed together by the Expansion of the Air in the *Thorax*, because the Lungs, having a Correspondence with the Receiver thro' the Wind Pipe, have no Air in them to extend the Lungs against the Expansion of the Air in the Cavity of the *Thorax*.

425. By the Ebullition or Appearance of boiling in warm Water or new Beer, under an exhausted Receiver.—*Exp.*

426. If a little Shell of a new laid Egg be cut off from the small End, on exhausting the Air out of the Receiver, the Spring of the Air contained in the big End of the Egg between the Film and Shell, will expand itself, so as to force the Contents of the Egg thro' the little Hole.—*Exp.*

427. That there is such a Bubble in Air is very evident

evident to Sight. Thus, cut off near half the Shell of the Egg, then placing the big End under a small Receiver, on exhausting, the Spring of the Air between the Shell and Film, will raise the Film or Skin to a considerable Height.—*Exp.*

428. Hence appears the Reason of that common Experiment of putting our Tongues to the greatest End of the Egg to judge of its Goodness, for if it feels cool, it is a Sign the Air is escaped, and then the Egg becomes stale, and at length putrid or addle.

429. Fountains are caused by the Springiness of the Air.—*Exp.*

430. Images sunk in Water are raised by exhausting the Air.—*Exp.*

431. That the Spring of the Air is equal to its Pressure.—*Exp.*

432. That large Quantities of Air are contained in most Bodies is easily shewn, by immersing dry Wood, Apples, new-laid Eggs, &c. in a Tumbler of Water, and placing the Tumbler under a Receiver, on exhausting, the Air will be seen to come out of the Pores of the Body, and rise thro' the Water, in an agreeable Manner.

Take an Apple just picked from the Tree, and stick a Piece of Brass, or some other Weight, to make it sink in the Tumbler of Water. Then exhausting the Air out of the Receiver, the Air will be seen to come out plentifully, especially from the Pin Holes.—*Exp.*

433. If a shrivelled Apple is made use of, you

N

will

will see Air come out of it, but not so plentifully, and the internal Air will expand the Skin till it becomes nearly, in Appearance, as full and fresh as when new.

434. *That Sound cannot be produced without Air. Exp.*

435. Take a lighted Candle and put under a Receiver. If the Receiver holds a Gallon, the Candle will go out in about a Minute, which shews that a Gallon of fresh Air is necessary to support the Burning of the Candle that Time.—The Smoke, by being lighter than the Air, rises to the Top of the Receiver, but not by any such Thing as positive Levity, which does not exist in Nature: For by exhausting the Air, the Smoke falls to the Bottom. *Ex.*

436. *Of Burnt Air*—to shew that Animals cannot live when the elastic Force of the Air is destroyed.—*Exp.*

437. *That Air is capable of being rarified by Heat.*

The *Eolipile* or Fountain by rarefied Air.—*Exp.*

438. The Bursting of Glass Hand-Grenades by heated Air.—*Exp.*

439. *That Air is capable of being condensed.*

Images in a Bottle raised and depressed, by only pressing with the Thumb on the Leather over the Neck of the Bottle.—*Exp.*

Because the Pressure of the Finger condenses the Air, which forces more Water into the Figures, and so renders them specifically heavier than the Water, and therefore they sink; but on taking off the Finger, the Air in the Figures, by its elastic Force, drives

out

out ſome of the Water, by which Means they become again lighter than the Water; and conſequently ſwim.—*Exp.*

440. A Fountain by condenſed Air.—*Exp.*

441. *Of Prince Rupert's Drops.*—Theſe are made of common Bottle Glaſs, by letting it, when intently hot, drop into Water, by which it becomes ſuddenly condenſed and very brittle, ſo that by only breaking off a little of its Top, the Whole breaks in Pieces.

442. *Of the Pulse Glaſs.*—This ſeems to be an Inſtance of the Exiſtence of Sir Iſaac Newton's Æther.



LECTURE XIV.

Of the Attraction of ELECTRICITY.

443. **T**HE Attraction of Electricity is a Species of Attraction peculiar to Glass, Amber, Sealing-wax, Jet, &c.—These Bodies by a strong Attrition attract and repel others that are very light, viz. such as are almost capable of being sustained from falling by the Medium of the Air; such as Feathers, Leaf-gold, &c.

444. The Multitude of Experiments which have been made are so great, that it would be in vain to attempt even to epitomise them. And amongst the large Detail of them, one scarce knows which to select as the most curious and important. To give them all would exceed any Bounds, which could be reasonably allotted to Lectures on this Subject.—However, it will be found in this as well as on the Air Pump, in Pneumatics, that though Experiments are numberless, yet almost every Thing we know on the Subject of Electricity, may be comprised in a few Propositions, in which are comprehended only *known Facts*; that young Auditors may not be imposed on, by the Speciousness of any Theory.

445. These Propositions I shall give as I find them ready drawn up, by the ingenious Dr. Priestly (Pages 435, 436, 437, 438, 439, and 440) in his laborious History of Electricity.

All

All known Substances are distributed by Electricians into two Sorts, those of one Sort are termed electric, or Non-conductors; and those of the other Non-electrics, or Conductors of Electricity.

446. Metals of all Kinds, together with Semi-metals, and all Substances in a State of Fluidity, except Air, are Conductors. So also is Charcoal, and other Substances of a similar Nature. All other Substances, whether mineral, vegetable, or animal, are Non-conductors. But many of these when they are made very hot, as Glass, Rosin, baked Wood; and perhaps, all the rest on which the Experiment can be made in this State, are Conductors of Electricity.

447. All Bodies, however, though in the same State of Heat and Cold, are not equally perfect Electrics, or perfect Conductors. Vegetable and animal Substances, for Instance, in their natural State, are seldom perfect Electrics, on Account of the Moisture that is contained in them. And, independent of Moisture, there is a Gradation in all Substances, from the most perfect Conductors to the most perfect Non-conductors of Electricity.

448. It is the Property of all Kinds of Electrics, that when they are rubbed by Bodies differing from themselves (in Roughness or Smoothness chiefly) to attract light Bodies of all Kinds which are presented to them; to exhibit an Appearance of Light (which is very visible in the Dark) attended with a snapping Noise, upon the Approach of any Conductor; and,

if the Nostrils be presented they are affected with a Smell like that of Phosphorus.

449. An electric Substance exhibiting these Appearances, is said to be excited, and some of them, particularly the Tourmalin, are excited by heating and cooling, as well as by rubbing.

450. It is necessary, however, to a considerable Excitation of any Electric, that the Substance against which it is rubbed (usually called the Rubber) have a Communication with the Earth, or Bodies abounding with Electricity, by Means of Conductors; for if the Rubber be insulated, that is, if it be cut off from all Communication with the Earth by Means of Electrics, the Friction has but little Effect.

451. When insulated Bodies have been attracted by, and brought into Contact with any excited Electric, they begin to be repelled by it, and also to repel one another: Nor will they be attracted again, till they have been in Contact with some Conductor communicating with the Earth; but, after this, they will be attracted as at first.

452. If Conductors be insulated, electric Powers may be communicated to them by the Approach of excited Electrics. They will then attract light Bodies, and give Sparks attended with a snapping Noise, like the Electrics themselves. But there is this Difference between excited and communicated Electricity, that a Conductor to which Electricity has been communicated, parts with its whole Power

at once, on the Contact of a Conductor communicating with the Earth; whereas an excited Electric, in the same Circumstances loses its Electricity only partially; it being discharged only from the Part which was actually touched by the Conductor, or those in the Neighbourhood of it; so that the Spark of electric Fire is not so dense, nor the Explosion made by parting with it so loud, from excited, as from communicated Electricity.

453. Electric Substances, brought into Contact with excited Electrics, will not destroy their Electricity; whence it is they are called Non-conductors, because they will not convey or *conduct* away whatever is the Cause of electric Appearances in Bodies.

454. When Electricity is strongly communicated to insulated animal Bodies, the Pulse is quickened, and Perspiration increased; and if they receive, or part with their Electricity on a Sudden, a painful Sensation is felt at the Place of Communication.

455. The Growth of Vegetables is quickened by Electricity.

456. No Electric can be excited without producing electric Appearances in the Body with which it is excited, provided that Body be insulated. For this insulated Rubber will attract light Bodies, give Sparks, and make a snapping Noise upon the Approach of a Conductor, as well as the excited Electric.

457. If an insulated Conductor be pointed, or if a pointed Conductor communicating with the Earth be held

held pretty near it, little or no electric Appearance will be exhibited; only a Light will appear at each of the Points, during the Act of Excitation, and a Current of Air will be sensible from off them both.

458. These two Electricities, viz, that of the Electric itself, and that of the Rubber, though similar to, are the Reverse of one another. A Body attracted by the one will be repelled by the other, and they will attract, and in all Respects act upon one another more sensibly than upon other Bodies; so that two Pieces of Glass or Silk, possessed of contrary Electricities, will cohere firmly together, and require a considerable Force to separate them.

459. These two Electricities, having been first discovered by producing one of them from Glass, and the other from Amber, Sealing-Wax, Sulphur, Resin, &c. first obtained the Names of *vitreous* and *resinous Electricity*; and it being afterwards imagined that one of them was a Redundancy, and the other a Deficiency of a supposed electric Fluid, the former (viz. that which is produced from the Friction of smooth Glass Tubes or Globes by the human Hand, or a common leathern Rubber) obtained the Name of *positive*; and the latter (viz. that which is produced from the Friction of Sticks or Globes of Sulphur, &c. or collected from the Rubber of a Glass Globe above-mentioned) that of *negative Electricity*: And these Terms are now principally in use.

460. If a Conductor, not insulated, be brought within the *Atmosphere*, that is, the Sphere of Action,

of



of any electrified Body, it acquires the Electricity opposite to that of the electrified Body; and the nearer it is brought, the stronger opposite Electricity doth it acquire; till the one receive a Spark from the other, and then the Electricity of both will be discharged.

461. The electric Substance which separates the two Conductors, possessing these two opposite Kinds of Electricity, is said to be *charged*. Plates of Glass are the most convenient for this Purpose, and the thinner the Plate, the greater Charge it is capable of holding. The Conductors contiguous to each Side of the Glass are called their *coating*.

462. Agreeable to the abovementioned general Principles, it is necessary, that one Side of the charged Glass have a Communication with the Rubber, while the other receives the Electricity from the Conductor; or with the Conductor, while the other receives from the Rubber.

463. It follows also, that the two Sides of the Plate thus charged are always possessed of the two opposite Electricities; that Side which communicates with the excited Electric having the Electricity of the Electric, and that which communicates with the Rubber, that of the Rubber.

464. There is, consequently, a very eager attraction between these two Electricities with which the different Sides of the Plate are charged; and, when a proper communication is made by Means of Conductors, a Flash of electric Light, attended with a Report (which is greater or less in Proportion to the Quantity

Quantity of Electricity communicated to them, and the Goodness of the Conductor) is perceived between them, and the Electricity of both Sides is thereby discharged.

465. The Substance of the Glass itself, in or upon which these Electricities exist, is impervious to Electricity, and does not permit them to unite; but if they be very strong, and the Plate of Glass very thin, they will force a Passage through the Glass. This, however, always breaks and renders it incapable of another Charge.

466. The Flash of Light, together with the Explosion between the two opposite Sides of a charged Electric, is generally called the *Electric Shock*, on Account of the disagreeable Sensation it gives any Animal, whose Body is made use of to form the Communication between them.

467. This electric Shock is always found to perform the Circuit from one Side of the charged Glass to the other by the shortest Passage, through the best Conductors. Common communicated Electricity also observes the same Rule in its Transmission from one Body to another.

468. It has been found that the electric Shock takes up the least sensible Space of Time in being transmitted to the greatest Distance.

469. The electric Shock, as also the common electric Spark, displaces the Air through which it passes; and if its Passage from Conductor to Conductor be interrupted by Non-conductors of a moderate Thickness,

ness, it will rend and tear them in its Passage ; and in such a Manner as to exhibit the Appearance of a sudden Expansion of the Air about the Center of the Shock.

470. If a strong Shock be sent through a small animal Body, it will often deprive it instantly of Life.

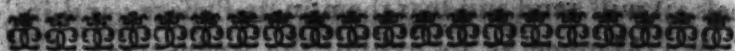
471. When the electric Shock is very strong, it will give Polarity to magnetic Needles, and sometimes it reverses their Poles.

472. Great Shocks, by which Animals are killed, are said to hasten Putrefaction.

473. Electricity and Lightning are, in all Respects, the same Thing. Every Effect of Lightning may be imitated by Electricity, and every Experiment in Electricity may be made with Lightning, brought down from the Clouds, by Means of insulated pointed Rods of Metal.

N. B. As many of these Propositions are proved by entertaining Experiments, as the Time allotted for a Lecture will admit.





LECTURE XV.

OPTICS.

Of Light in general.—CATOPTICS.—The general Laws of reflected Light.—Properties of Plane, Concave and Convex Mirrours.—Deformed Figures appearing regular in a Cylindrical Mirrour.

474. **B**Y OPTICS we understand the Science of Vision, with the Properties of Light, and the various Instruments which have been invented to assist our Sight.

475. By Rays of Light, says that excellent Optician, Sir *Isaac Newton*, I understand its least Parts, and those as well Successive in the same Lines as Contemporary in several Lines.

For it is manifest that Light consists of Parts both Successive and Contemporary; because in the same Place you may stop that which comes one Moment, and let pass that which comes presently after; and in the same Time you may stop it in any one Place, and let it pass in any other. For that Part of Light which is stopt cannot be the same with that which is let pass. The least Light, or Part of Light, which may be stopt alone without the Rest of the Light, or propagated alone, or do or suffer any Thing alone which the Rest of the Light does not, or suffers not, I call a Ray of Light.

476. A

476. A *Beam of Light* is a sensible Part of it, consisting of a great Number of Rays.

477. A *Pencil of Rays*, is a Portion of Light of a conical Form, proceeding from a Point, or else tending to a Point.

478. *Parallel Rays* are such as run in parallel Directions; *converging Rays* are those that tend to a Point; and *diverging Rays* are such as proceed from a Point.

479. A *Medium* is whatsoever the Rays of Light pass thro', as Water, Oil, Glass, Air, or any transparent Body; and even a Vacuum.

The principal Properties of LIGHT are,

480. That it proceeds from the Surface of a visible Body in all Directions.

481. That the Light thus emitted from Bodies in all Directions is propagated in right Lines.

482. That the Quantities of Light received upon any given Surface will decrease in the same Proportion as the Square of the Distance of that Surface from the luminous Body is increased.

483. By the same Method of Reasoning which proves this Article may be shewn, that the Intensity of Fire, Odours, &c. decrease, in the same Proportion as the Square of the Distance increases.

Thus, for Example. If two Men, A and B, are warming themselves, viz. A, four Feet from a Fire, B, 16; that is, their Distances being as 1 to 4; (and 4 multiplied by 4 being equal to 16, and 1 mul-

O

tiplied

multiplied by 1 equal to 1) it will be 16 Times as hot to A as to B.

484. That the Progress of Light is not instantaneous, but takes up about 7 or 8 Minutes in passing over the Diameter of the Earth's Orbit, appears by the Observations of the Eclipses of Jupiter's Satellites.

485. That the Velocity of Light bears a sensible Proportion to the Velocity of the Earth's Motion in its Orbit, appears from Dr. *Bradley's* Discovery of the Abberation of Light.

486. The Velocity of Light is amazingly great, being about two million Times greater than that of a Canon Ball.

487. From what has been shewn it is plain, that Light is a material Substance, or what we call a Body.

488. The Particles of Light are extremely small; and is a remarkable Instance of Divine Wisdom; for if a Particle of Light weighed but $\frac{1}{1000000}$ Part of a Grain, it would strike with as great a Force as a Canon Ball of 10lb. Weight.

489. That Bodies act on Light, appears from the Rays being reflected and refracted, as will be shewn in these Lectures.

Of CATOPTRICS.

490. Having considered Light in general, we come now to explain the Nature of reflected Light

Light, from Glass or Metal Mirrours, or Speculums, &c.

491. If a Ray of Light falls perpendicularly on a Plane Mirrour or Looking-Glass, &c. it will be reflected directly back again. But if it falls obliquely, it will be reflected so as to make the *Angle of Incidence equal to the Angle of Reflection*, That is, Pl. III. Fig. 3. The incident Ray FC will be so reflected in the Direction CD, as to make the Angle FCE, or that of Incidence, equal to the Angle ECD of Reflection. Hence the Angle FCA is equal to the Angle DCB. *Exp.*

492. It is a Maxim, that *Nature*, or rather the God of Nature, does every Thing in the *shortest* Way; and it is indeed a Principle which seems to follow from the Idea of every Thing being ordered by *infinite Wisdom*; and as far as it has been applied, has always been found agreeable to the Nature of Things. From this Principle it is easily demonstrated in my *Accountant and Geometrician*, that in order for the Ray of Light to pass in the shortest Way possible, the Angle of Incidence must be equal to the Angle of Reflection.

493. Sir *Isaac Newton* has shewn that the Particles of Light are reflected back before they actually touch the reflecting Surface; *contrary* to the Opinion of all who wrote before him.

CONVERGING and DIVERGING RAYS.

494. When Rays tend to meet in a Point, as the solar Rays do when they pass thro' a common dou-

ble convex reading Glass, as represented in Pl. III. Fig. 4. they are then called *Converging Rays*; And because the Rays so collected and condensed into that Point, will actually burn, it is called the *Focus*, and sometimes the *Principal Focus*.

495. But when the Rays spread wider asunder, as the solar Rays do in passing thro' a concave Glass, or such a one as is used by short-sighted People, as represented in Pl. III. Fig. 5. they are then called *Diverging Rays*; and then the Point on the other Side of the Glass, from which they seem to have come, is called the *Imaginary Focus*, to distinguish it from the Focus of a convex Lens, which is real.

496. The second Law of Catopticks is, that every radiant Point when seen by Reflection, appears in that Place where the reflected Ray produced, meets the Perpendicular drawn from the radiant Point to the reflecting Surface.

Thus in Pl. III. Fig. 6. if a radiant Point R be seen by Reflection from the Surface AB by an Eye at D, its Image will appear at I where the reflected Ray DC produced meets AI, a Line drawn from R perpendicular to the reflecting Surface AB. The Exp. which proved the 1st Law, also shews this.

497. We may now proceed to some of the Properties of Mirrours, and first of Plane Mirrours.

PLANE MIRROURS.

Rays that are parallel when they fall on a Plane Mirrour, will be parallel when they are reflected by it.—Exp.

498. Rays

498. Rays diverging from any radiant Point, and falling on a Plane Mirrour, will diverge after Reflection, as if they came from an imaginary Focus, as far behind the Mirrour, as the radiant Point is before it.—*Exp.*

499. From what has been said, it appears that if an Object be seen by Reflection from a plane Surface, its Image appears as far behind the Speculum, as the Object is before it.

500. In Plane Mirrours the Image is equal and similar to the Object.—*Exp.*

501. If a Plane Mirrour and the Object that is seen in it are both perpendicular to the Horizon, the Object seen in the Mirrour appears erect.—*Exp.*

502. If a Person sees himself entirely in a Plane Looking-Glass, which is parallel to him, the Glass must be half as long, and half as broad, as he is.

503. In a Plane Mirrour, what is on the Right Hand Side in the Object, is on the Left Hand Side in the Image, *et contra*.—*Exp.*

504. If a Plane Mirrour is parallel to the Horizon, such Objects as are perpendicular to it, appear inverted.—*Exp.*

505. If a Plane Mirrour is inclined to the Horizon in an Angle of 45 Degrees, any Object which is parallel to the Horizon will appear erect in it; and on the contrary, an Object which is perpendicular will appear parallel to the Horizon.—*Exp.*

506. Hence it follows, that if the Mirrour and Object remain unmoved, the Image will appear the same in any Situation of the Eye.

507. Hence also in Mirrors which have but one reflecting Surface, only one Image of an Object can be seen: But in Glass Mirrors which have a double Reflection, in some Positions of the Eye, several Images may be seen. — *Exp.*

508. Two *Plane Speculums*, being placed parallel to each other, and an Object between them, the Rays proceeding from the Object, and falling on each Speculum, will be reflected backward and forward from one to the other, so as to cause an Appearance of several Images in each Speculum, one behind another in a right Line, perpendicular to the Planes of the Speculum or Mirrors. — *Exp.*

509. If two *Plane Speculums* be inclined to each other, so as to meet in an acute Angle, an Object placed between the Speculums, will to an Eye looking into either of them, appear to form several Images standing in the Circumference of a Circle, whose Center is in the Vertex, or angular Meeting of the Speculums, and Radius equal to the Distance of the Object from the Vertex. — *Exp.*

510. If the Distance of the Object from the Vertex remains the same, whatever the Angle be, the Images will still appear in the Circumference of the same Circle. — *Exp.*

Of SPHERICAL MIRRORS.

First of Concave Mirrors.

511. A *Concave Spherical Mirror* has a real Focus.

If

If it be held directly before the Sun, and a small Piece of Paper be held before it to receive the reflected Rays; move the Paper backward and forward till the Spot of Light be the least possible, and that is the principal Focus.

512. The incident solar Rays may be looked on as parallel to each other, and in such Case the focal Distance is equal to half the Radius of the Speculum; and the Image will appear on the Focus, on the same Side as the radiant Object. — *Exp.*

513. If the Speculum be large enough to collect a sufficient Quantity of Solar Rays, to be condensed in the Focus, it will burn in that Point; hence this Point is also called the *Focus*.

514. As an Object approaches the Speculum, the Image recedes. — *Exp.*

515. Upon the Object's passing from the Center (of Curvature of the Speculum) towards the Mirror, the Image is projected beyond the Center, and when the Object is but half the Radius of the Mirror, or in the principal Focus, the Image is at an infinite Distance, or to speak more properly, the Rays after Reflection become parallel: For which Reason, if the Flame of a Candle be placed in the principal Focus, the Mirror will seem all in Flames, and the reflected Light will be so intense, as by the Help of it, we may read at a considerable Distance. *Tacquet* affirms that he had read at no less a Distance than 400 Feet.

516. When

516. When the Distance of the Object from the Speculum is less than half the Radius, the Image appears behind the Speculum, As the Object moves nearer to the Speculum before, so likewise does the Image behind; and when the Object is so near as to touch the Speculum, the Image does the same.

Exp.

517. As to the Position of Images seen by Reflection from a Concave Mirrour, those which appear on the same Side of the Speculum with the Object are inverted, and those which appear behind the Speculum are erect.—*Exp.*

518. The Length or Breadth of an Object and its Image, are to one another, as their Distances from the Speculum.

519. Hence it follows, that the Object during its Continuance beyond the Center, must appear larger than its Image, as being more distant from the Mirrour. When it is in the Center where it meets the Image, must appear equal to it; But when it is on the same Side of the Center with the Speculum, it must be less than its Image; which in that Case lies beyond the Center, and, consequently, at a greater Distance from the Mirrour.—*Exp.*

520. Hence also, the Image that appears behind the Speculum is always larger than the Object,—*Ex.*

OF CONVEX MIRROURS.

521. The Focus of Convex Mirrours is imaginary.—*Exp.*

522. The

522. The Focal Distance, or Distance of an Image behind the Convex Mirror, may be found by saying, as the Sum of the Radius and twice the Distance of the Object from the Speculum is to the Distance, so is the Radius to the Focal Distance (behind the Speculum) required.

523. Hence it follows, that if the Object touches the Mirror, the Image does so likewise. — *Exp.*

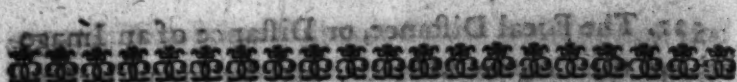
524. Hence also the Image of parallel Rays appear behind, in the Midway between the Speculum and its Center.

525. Hence it appears that Objects seen by Reflection from convex spherical Speculums, appear constantly behind the Speculum, within the Limits of $\frac{1}{2}$ the Radius; and forasmuch as the Images constantly appear on the same Side of the Center with the Objects, they must be less than the Objects.

526. The Proportion which the Length or Breadth of an Object and its Image, bear to one another, is the same with that of their Distances from the Speculum, as in Concave Mirrors.

527. Images seen by Reflection from Convex Speculums always appear erect. — *Exp.*

528. Deformed Pictures may be so drawn as to appear regular in a Cylindrical Mirror. — *Exp.*



LECTURE XVI.

DIOPTRICS.

Of refracted Light, through Water and Glass Lenses.

529. **W**HEN a Ray of Light passes perpendicularly out of one Medium into another, it proceeds in a right Line, or in other Words, suffers no Refraction.

530. Hence the Reason why the apparent Place of a Star in the Zenith, is the same as its true Place,

531. But if a Ray of Light passes obliquely out of a rarer into a denser Medium, it will be refracted or bent towards the Perpendicular, *et contra*.

532. The general Law is, if a Ray of Light passes obliquely out of Air into Water, the Sines of the Angles of Incidence and Refraction are in the constant Ratio of 4 to 3, *et contra*.

Thus in Plate III. Fig. 7, If AC be the incident Ray, and CB the refracted Ray, if the Sine of Incidence AE be equal to 4, the Sine of Refraction BD is equal to 3. But if the Refraction be out of Air into Glass, the Sine of Incidence is to the Sine of Refraction as 17 to 11.

533. Hence we see the Reason why any Thing appears higher in Water than in an empty Vessel. Thus every Person who has been in a Boat may remember,

ber, that an Oar, Part being in the Water, appears turned up, as if broken.

534. If we view a Shilling in the Bottom of a Basin or Tumbler, in a perpendicular Direction, it will appear about $\frac{1}{4}$ higher when covered with Water, than when the Vessel is empty.

535. The Eye may be so deceived that a Shilling shall appear to be equal to 3s. 6d.

536. The Bending of the Rays in their Passage out of one Medium into another, seems to be owing to the attractive Force of the denser Medium, acting upon the Ray at right Angles to the Surface.

537. What farther confirms this Opinion is, that the denser any Medium, and consequently the stronger its Attraction, the greater, *ceteris paribus*, is its refractive Power: Thus Oil of Vitriol, whose Density exceeds the Density of Water in the Proportion nearly of 3 to 2, acts more forcibly than Water upon the Rays of Light, in bending and turning them out of their Way.

538. Hence the Reason is evident why the Sun, Moon, &c. by the Rays of Light coming through the dense Medium of the Atmosphere, appear higher than they really are; and that this Refraction is greater near the Horizon, than higher up: And in the Vertex it is nothing.

539. Hence the Sun, Moon, and Stars may be seen when they are below the Horizon.

540. For this Reason it appears, that those Sailors who take the Sun's Amplitude at Rising or Setting

(in

(in order to determine the Variation of the Compass) when the Sun appears in the Horizon, may etc. considerably in the Amplitude, and consequently in the Variation; because, at the Time it appears in the Horizon, it is 33 Minutes under. And therefore the Observation ought to be made, when the Sun appears about half its Breath clear of the Horizon; for then its Center is really in the Horizon.

541. Hence also we see the Reason why the Sun and full Moon, when rising, appear of an oval Figure, viz. broader than high.—*Exp.*

542. When a Ray of Light passes out of Water into Air, the Angle of Incidence is less than the Angle of Refraction, and the refracted Ray departs from the Perpendicular as the Angle of Incidence increases: it therefore follows, that when the refracted Ray is nearly parallel, or coincident with the Surface of the Medium upon which it falls, the incident Ray will make an Angle with it.—In Water when the Angle of Refraction is 90° , the Angle of Incidence will be about 48° ; it is easy therefore, to understand, that if the Ray falls with a greater Obliquity than 48° , it will be wholly reflected back again, and none will go out into the Air at either Surface of the Medium,

543. If the Medium be Glass, the Angle of Incidence is 41° when the refracted Ray becomes coincident with the Surface of the Medium; and therefore, when the Angle is greater, the Light will be wholly reflected from one Side of the Glass to the

to the other, and never let out into the Air: Whence it follows, that though the Particles of Matter in Bodies be in themselves transparent, yet if they are so disposed one among another as to reflect the Light very obliquely, 'tis plain, the Light in such a Case will be lost by various Reflections within the Body, and thus prove a Cause of the Opacity of the Body.

Of LENSES.

543. We now proceed to consider the Nature of Light passing through the different Kinds of Lenses.

Of GLASS LENSES.

544. Prop. 1st, When parallel Rays fall on a convex Surface, in passing out of a rarer into a denser Medium, as out of Air into Water, they will converge.

545. Prop. 2d, When parallel Rays fall on a concave Surface, in passing out of a rarer into a denser Medium, as out of Air into Water, they will diverge.

546. As a Plano-Convex, Plate III. Fig. 8; a Double Convex, F. 9; a Plano-Concave, F. 10; Double Concave, F. 11; a Meniscus or Lunette, F. 12.

547. Prop. 3d, When parallel Rays fall on either Surface of a Plano-Convex Lens, they are refracted

P

towards

towards each other, and collected into a Point called the Focus; on the other Side of the Lens. In both the focal Distance is the same, and equal to the Diameter of its convex Side.—*Exp.*

548. Prop. 4th, If parallel Rays fall directly upon a double Convex Lens, which is equally convex on both Sides, they will converge after they have passed through it, to a Focus, which will be at a less Distance from the Lens than that in the last Proposition; viz. the focal Distance equal to the Semidiameter of either of its Surfaces.—*Exp.*

549. The Point in which Parallel Rays are collected by passing through the Lens, is called the *Principal Focus*, or the Focus of Parallel Rays of that Lens.

550. Convex Lenses are burning Glasses, because they collect the Rays of the Sun into a Point; which is therefore called the *Focus*, or *Burning Point*.

551. The solar Fire, or Heat of the Sun's Rays is found, even at the great Distance we are placed from him, to be more intense than that of any Fire whatsoever. For so small a Quantity as is collected in the Compass of a common reading Glass will actually burn; and the Rays which fall within the Compass of some of our Glasses or Mirrours, will exceed the Power of the greatest Culinary Fire; as is manifest from their burning or vitrifying almost instantaneously the most obdurate and combustible Bodies, such as not only green Wood and

white

white Bodies; but also Stones, Bricks, Metals, and even Gold itself (the hardest of all Metals to be wrought upon by Fire) which yet is melted down in a few Minutes.

A Silver Six-pence hath been melted in 7 Seconds and half.

A Copper Half-penny ran with a Hole in 30 Seconds.

Tin melted in 3 Seconds.

Cast Iron melted in 16 Seconds.

Slate melted in 3 Seconds.

This was by Mr. Vilette's Mirrour of 3 Feet 11 Inches Diameter, and focal Distance 3 F. 2 I.

This Mirrour condenses the Rays 17257 Times; and Rays but 35 Times denser than common Rays have a Power of burning equal to Wood Fire; and 17257 divided by 35 gives 493; therefore the Intensity of the Solar Rays so condensed is 493 Times greater than common Fire.

552. Prop. 5th, Parallel Rays become diverging thro' a Plano-Concave Lens.

In this, the Focus is called the *Imaginary Focus*, by some the *Imaginary Radiant*, by others the *Virtual* or *Negative Focus*, because the Rays do not meet in that Point, but when they have diverged, only appear to have as it were issued from that Point. Whether the Rays are incident on the Plane or Concave Side, the Focal Distance is the same, viz. equal to the Diameter of its Concave Surface.

553. Cotollary. Hence, Plano-Convex and Plano-Concave Lenses, of equal Radii, have equal Focal Distances, only one is real, the other imaginary.

554. Prop. 6th. If Parallel Rays fall directly on a double Concave Lens, of equal Concavity, they will diverge after they have passed through it, and their Divergency will be greater than in the last Proposition, or which is the same Thing, their virtual Focus will be less, viz. equal to the Semidiameter of Concavity.

555. Hence a double Convex and double Concave Lens have equal Focal Distances, only one is real and the other imaginary.

556. Prop. 7th. If Parallel Rays pass through a Meniscus or Lunette, that is, a Lens, one of whose Sides is convex the other concave. If the Concave is a Portion of a smaller Sphere than the Convex, the Rays will diverge after passing thro' it; if the contrary, they will converge: but the Effect of this Lens will be least, because each Surface produces a contrary Effect. In this, as the Difference of their Radii is to twice either Radius, so is the other Radius to the Focal Distance.

If the Radii are equal, the Focus is infinite, or the Rays will go parallel.

557. The Magic Lantern is too well known to require a Description.

LECTURE XVII.

Of VISION.

558. IN order to understand the Nature of Vision, it is necessary to describe the Structure of the Eye; at least so far as is necessary to Vision.

The outermost Coat B N B is called *Sclerotica*; its Forepart is transparent, and called *Tunica Cornea*, Pl. IIII. Fig. 13.

The *Choroides* is as it were a Lining to the Inside of the *Sclerotica*.

Inside the *Cornea*, at a small Distance, is a circular Diaphragm Bo, Bo, called *Uvea*; the Hole in it is called the *Pupil*, and the Circumference, or rather Ring of the Hole, is called *Iris*: Ba, Ba, the *Ligamentum Ciliare*; a z a is the *Retina*, or Expansion of the Optic Nerve Z I. The *Aqueous Humour* is contained betwixt the *Ligamentum Ciliare*, *Crystalline*, and *Cornea*. H a a G is the *Crystalline*; and the remaining Part G Z H the *Vitreous Humour*.

Note, in the human Eye, some Authors take the *Iris* and *Uvea* to be the same Thing, But there being no such Thing of the Colour of an unripe Grape, the Term *Uvea* should be omitted.

559. Those who have black Eye-lids have com-

monly the best Sight, and those which are very fair or white, the worst.

560. Looking at the Sun is dangerous; white Objects are prejudicial; but green agreeable to the Eye.

561. The *Optic Nerves* do not enter at the Middle of the Bottom of the Eye, but nearer the Nose; for those Rays of Light which fall on the Entrance of the Nerve, being ineffectual for Vision, it is necessary they should be placed as they are, that the same Object which happens not to be seen by one Eye may be seen by the other.

This may be illustrated by a well known Experiment of three Pieces of Paper.

562. The Image of an Object is *inverted* on the Bottom of the Eye in the same Manner as the Image is painted on Paper in the Focus of a double convex Glass. ——— Pl. IV. Fig. 14. where A B represents an Object, *a b* its Image.

563. Distinction of a Picture is not the same Thing as its Brightness: Nor is the Confusion of its Parts the same Thing as its Obscurity.

564. When an Object is very near the Lens, to make a distinct Picture the Area of the Lens must be very small.

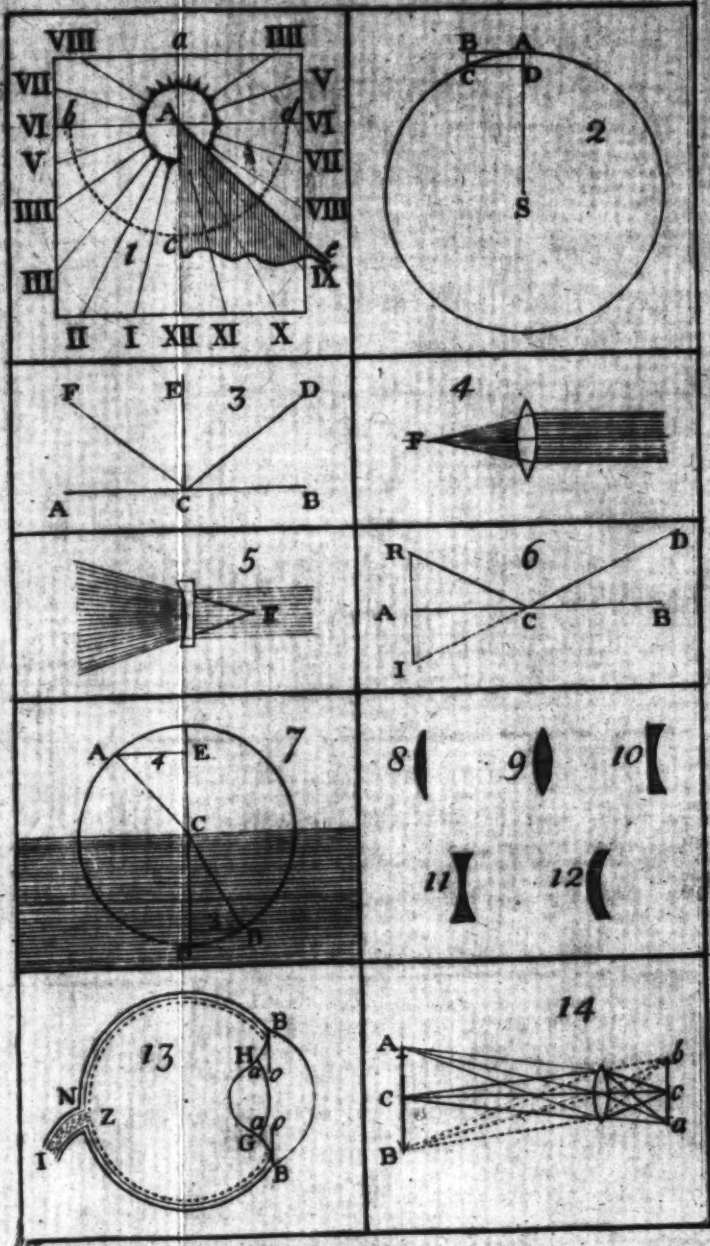
565. Hence appears the Reason why in Microscopes, the principal magnifying Glass is very small.

566. Eye-Brows are peculiar to Man.

567. The Sight is commonly best when the Hairs of the Eye-Brows are black, and worst when white.

568. A dilated Pupil is a Sign of a bad Eye.

569. In



569. In Men the Pupil is round, to look every Way, in Beaſts oblong horizontally, to ſee a large Space on the Earth; Cats and other Animals which climb Trees, feed on Birds, or that hide in the Earth, have their Pupils oblong vertically, to enable them to ſee upwards and downwards.

Of the HUMOURS of the EYE.

570. The firſt, or *Aqueous Humour*, is ſo called from its Reſemblance to Water, in its ſpecific Gravity, refracting Power, &c.

571. The *Cryſtalline Humour* is ſo named from its apparent Likeneſs to Cryſtal. Its ſpecific Gravity very little exceeds that of Water, viz. in the Proportion of 11 to 10. Hence it appears this muſt not be looked on as the only or principal Cauſe of Viſion, as is done by moſt Writers. It is contained in a moſt delicate Tunic, Capſula, or Coat, called *Arachnoides*.

572. The laſt or *Vitreous Humour* is ſo called from its being like Glaſs, and is the Greateſt of all in Quantity. Its ſpecific Gravity, &c. but a little exceeds that of Water.

573. The Forms and refractive Powers of theſe ſeveral Humours, are ſuch, as accurately converge parallel Rays to a Focus upon the Retina, in the Bottom of the Eye, as may be proved by Mathematical Calculations; from the Dimensions taken at a Mean from ſeveral Eyes.

574. It

574. It is found by Experience, that the nearest Limit of distinct Vision is about six Inches from the Eye.

575. Indistinct Vision may in some Degree be remedied by lessening the Pupil, which we naturally do by contracting the annular Fibres of the Uvea, and artificially by looking thro' a small Hole, in a Card, &c.

576. Besides the Contraction of the Pupil we have a Power of altering, in some Degree, the Form of the Cornea, it being of an elastic yielding Surface, and the Crystalline being inclosed with a little Water in its Capsula, seems capable of having the Convexity of both its Surfaces a little altered by the Contraction and Relaxation of the Ciliary Ligament; by which Means the Distance from the Retina may be adapted to different Distances for near Objects; as between 6 and 100 Inches Distance; Objects more remote requiring scarce any Alteration in the Form of the Eye.

577. As Objects appear indistinct by being too near the Eye, so they do also by being too remote: for it is found by Experience that Objects appear indistinct when they subtend a less Angle than $\frac{1}{16}$ of a Degree or 6 Minutes.

Thus, for Example, an Object or Circle $\frac{1}{16}$ of an Inch Diameter becomes indistinct at the Distance of about 6 Feet; if $\frac{1}{8}$ of an Inch at about 12 Feet.

578. Sir ISAAC NEWTON says in his Optics, "That Anatomists, when they have taken off from the

Bot-

Bottom of the Eye that outward and most thick Coat called the *Dura Mater*, can then see thro' the thinner Coats the Pictures of Objects lively painted thereon. And these Pictures propagated by Motion along the Fibres of the optic Nerves into the Brain are the Cause of Vision. For accordingly as these Pictures are perfect or imperfect the Object is seen perfectly or imperfectly. If the Eye be tinged with any Colour (as in the Disease of the Jaundice) so as to tinge the Pictures in the Bottom of the Eye with that Colour, then all Objects appear tinged with the same Colour. If the Humours of the Eye by old Age decay, so as by shrinking to make the Cornea and Coat of the crySTALLINE Humour grow flatter than before, the Light will not be refracted enough, and for want of a sufficient Refraction will not converge to the Bottom of the Eye, but to some Place beyond it, and by consequence paint in the Bottom of the Eye a confused Picture, and according to the Indistinctness of this Picture the Object will appear confused. This is the Reason of the Decay of Sight in old Men, and shews why their Sight is mended by Spectacles. For those Convex Glasses supply the Defect of Plumpness in the Eye, and by increasing the Refraction make the Rays converge sooner, so as to convene distinctly at the Bottom of the Eye, if the Glass have a due Degree of Convexity. And the contrary happens to short sighted Men whose Eyes are too Plump. For the Refraction being now too great, the Rays

converge

converge and convene in the Eyes before they come at the Bottom; and therefore the Picture made in the Bottom and the Vision caused thereby will not be distinct, unless the Object be brought so near the Eye as that the Place where the converging Rays convene may be removed to the Bottom, or that the Plumpness of the Eye be taken off and the Refraction diminished by a Concave Glass of a due Degree of Convexity, or lastly that by Age the Eye grow flatter till it come to a due Figure: For short sighted People see remote Objects best in old Age, and therefore they are accounted to have the most lasting Eyes."

579. An Object seen by Refraction (by the Bye it is true also in Reflection) appears in the Plane from whence the Rays after their last Refraction diverge, in falling on the Spectator's Eye.

580. We might now proceed to treat of the Disorders of the Eyes; of the Nature of Vision by Glasses; to shew why Convex Glasses magnify, and Concave diminish Objects; of the Construction of Microscopes, Telescopes, &c; but these Subjects require more Room than is consistent with the designed Brevity of this Work. We must therefore pass on to the Doctrine of Colours.

LECTURE XVIII.

OPTICS.

Of the Newtonian Doctrine of Colours.

581. **T**O SIR ISAAC NEWTON we are indebted for almost every Thing we know of the Nature of Light. We shall therefore proceed to the principal Propositions and Experiments necessary to explain his Theory.—First then, notwithstanding the uniform Appearance of Light, the Particles whereof it is composed are of different Colours. This is shewn by the *Exp.* of the *Colour'd Spectrum*, viz. Letting the Beams of the Sun's Rays through a Hole in the Window-Shutter of a dark Chamber, they will be refracted by a Glass Prism, and if the Image be received on White Paper or the White Wall, it will be found that the Rays will be differently refracted, viz. the least will be Red, the next Orange, then Yellow, Green, Blue, Purple, and the most refrangible Violet.

N. B. Five of these Colours may be easily seen, but it is not so easy to distinguish all Seven.

582. If Rays be refracted a second Time, that which was most refracted at first will be so the second Time. And if a single Colour be refracted a second Time, it cannot be changed; but will retain the same Colour it had at first. This proves that

that the Colours are not any thing accidental in the Refraction thro' the Prism, but are absolutely in the Solar Rays.—*Exp.*

583. Nor can these Colours be changed by Reflection. For if differently colour'd Bodies be placed in a Red Light they will appear Red, and in a Blue Light they will appear Blue, in Green light Green, and so of the other Colours; in the Light of any one Colour, they will appear of that Colour, only that every Body will appear more splendid and luminous in the Light of its own Body. — *Exp.*

584. Since the Colours of Rays are not capable of being changed either by Reflection or Refraction, it follows, that if the Sun's Light consisted but of Rays of one Colour only, then every thing would appear of that one Colour. Hence also it follows, that the Reason we see Bodies appear of different Colours, arises from their Aptness to reflect some Sort of Rays more copiously than the rest.

585. These Colours which we observe in the Rays of Light, are therefore properly called the Original or Primary Colours.

586. Colours the same in Specie with these Primary ones may be also produced by Composition. For a Mixture of Yellow and Blue makes Green, of Red and Yellow makes Orange, of Orange and Yellowish Green makes Yellow. And in general, if any two Colours be mixed, which in the Series of those generated by the Prism are not too far distant

distant from one another, they by their mutual Alloy compound that Colour, which in the said Series appears in the Midway between them. But these which are situated at too great a Distance, do not so. Orange and Indigo produce not the intermediate Green, nor Scarlet and Green the intermediate Yellow.

587. But the more surprising and wonderful Composition is that of Whiteness, and to its Composition are necessary all the aforesaid Primary Colours mixed in due Proportion. Hence therefore it comes to pass that Whiteness is the usual Colour of Light.

588. The Reason why Bodies reflect this or that Kind of Rays more copiously than the rest, and consequently appear of this or that Colour, Sir *Isaac Newton* has shewn in his second Book of Optics, to depend entirely on the Size and Density of the Particles whereof the Bodies are composed. That *Red* is reflected by Particles of the greatest Thickness, and that the Thickness of the Particles which reflect the other Colours, grows less and less, as the Colours which they reflect are more and more removed from the Red. Also that amongst the Particles which reflect one and the same Colour, those which have the greatest Density, have the least Thickness.

589. From what has been said concerning the Colours of Natural Bodies, it follows, that if any Change be made in the Size or Density of the Par-

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ticles

ticles whereof a Body is composed, the Colour of the Body will be likewise changed. For which Reason if two colourless Liquors be mixed together, they may in mixing suffer such Changes in the Size and Density of their Parts, from their mutual Actions upon one another, as to become opaque and coloured; and such Liquors as are coloured, may for the same Reason, when mixed together, either become transparent and colourless, or of such a Colour as is different from the Colour of either before the Mixture. As may be proved by Experiments.

Of the RAINBOW.

590. Amongst the various Phænomena of Colours, we have none more remarkable than that of the *Rainbow*. Every Person may observe that this Appearance is only seen where it rains when the Sun shines, and the Spectator placed in a particular Situation between the Sun and Rain, with his Back towards the Sun.

This Phænomenon has in some Degree been illustrated by *Antonius de Dominis*, Archbishop of *Spalato*, in the Year 1611, and after him by *Des Cartes*; but as they were not acquainted with the true Origin of Colours, it was reserved to Sir *Isaac Newton* to give a compleat Solution thereof, and which he has done in his first Book of Optics.

591. There are generally two Rainbows one over the other; the lowest or interior one is called the Primary,

Primary, and is made by two Refractions and one Reflection of the Rays in the spherical Drops of Water. — The secondary Bow, is occasioned by two Reflections and two Refractions and therefore appears less bright, as every Reflection must diminish the Brightness of the Colour.

592. If we conceive a Line drawn from the Spectator's Eye towards the Bow, parallel to the Direction of the Solar Rays; then it is proved by Calculation, that if this Line makes with another Line conceived to be drawn from the Bow to the Eye, an Angle of $42^{\circ} 2'$, the Spectator will perceive a Red Ray in the Upper Part of the Primary Bow; and if a Drop is seen under an Angle of $40^{\circ} 17'$, he will see a deep Purple or Violet Colour in the lower Part of the Primary Bow.

593. If the Angle be $54^{\circ} 7'$, the Spectator will perceive the Violet in the upper Part of the Secondary Bow; if an Angle of $50^{\circ} 57'$ he will see a Drop in the under Part of the Secondary Bow of a Red Colour.

And between these, the intermediate Colours in the Primary; the Colours from the Inside of the Bow to the Outside are in this Order, *Violet, Indigo, Blue, Green, Yellow, Orange, and Red.* In the Secondary Bow the Order is reversed.

594. Hence the Breadth of the interior Bow measured across the Colours should be $1^{\circ} 45'$; the Breadth of the exterior $3^{\circ} 10'$, and the Distance between them $8^{\circ} 55'$; the greatest Semidiameter of the

the Innermost $42^{\circ} 2'$, and the least Semidiameter of the Outermost $50^{\circ} 57'$; and if the Sun was of no apparent Diameter these would be the real Breadths.

595. But, as the Diameter of the Sun is about $32'$ the Breadth of the Bows will be increased, and their Distance lessened by that Sum.

596. Hence the Breadth of the interior Bow will be $2^{\circ} 17'$, the Breadth of the exterior $3^{\circ} 42'$ and their Distance $8^{\circ} 23'$. And so the greatest Semidiameter of the interior Bow will be increased by the Semidiameter of the Sun, and that of the least Exterior lessened by as much: Hence the greatest Semidiameter of the interior Bow is $42^{\circ} 18'$ and the least Semidiameter of the Exterior $50^{\circ} 41'$. And agreeable to these Dimensions have the Measures been actually found in the Heavens.

597. *Note*, In a Garden where a Fountain is playing sufficiently high, if a Person stands between the Sun and the Fountain, with his Back towards the Sun, then by moving backwards or forwards till he is in a proper Position, he may have an experimental Proof of this Doctrine of the Rainbow.

598. Thus have we taken a Survey of the principal Laws by which the material World is governed; and even from this cursory and hasty View of Things, does it not evidently appear to be in the greatest Degree absurd, to suppose that Chance or a fortuitous Concourse of Atoms could be the Cause of so much Order and Regularity? Even so great, that nothing less than Infinite Goodness, Wisdom and Power, seems capable of willing, contriving and executing!

Hence Sir *Isaac Newton* at the End of his *Principia* might well observe, that to discourse of God from the Appearances of Things, does certainly belong to Natural Philosophy.

The END of the LECTURES.

T H E
U S E O F T H E

* I M P R O V E D A N A L E M M A .

IT is well known to Masters of Academies who teach Geography and the Use of the Globes, to Youths, whose Parents are not inclined to purchase a Pair of Globes, that after some Time, for want of Opportunity to practise, great Part of what they have learnt, slips their Memory. I am therefore inclined to think, that the Analemma now offered to the Public will be acceptable, as it will in a great Measure supply the Want of a Celestial Globe, as a common Map of the World does in some Degree, that of the Terrestrial.

2. In the Year 1721 my Father (GEORGE DONN) then Teacher of Practical Mathematics at *Bideford, Devon*, engraved an Analemma on Brass, for his own Use, particularly constructed to solve Problems concerning the Sun; which to render more generally useful, I have now adapted to work the usual Problems relating to the Planets, Moon, and Stars, as well as those of the Sun.

3. The moveable Circle or what is commonly called the *Analemma*, is an orthographic Projection of the Sphere on the Plane of the Meridian.

4. The dotted Line which passes through the Center is the *Equinoctial*, the Lines parallel to it are
R Parallels

* Sold by the Author, B. DONN, in Bristol;—also by Messrs. HEATH and WING, Mathematical Instrument-Makers in the Strand; B. LAW, in Ave-mary-lane; and G. KEARSLEY, on Ludgate Hill, (Bookfellers) London,——Price 3s. 6d.

Parallels of Declination ; and for the readier counting, every 5th Degree is engraved stronger than the others

5. The Line which passes thro' the Center and is perpendicular to the Equinoctial is the *Axis*; one End of which marked with a Fleur-de-Lis is the *North Pole*, as the other End marked S, is the *South Pole*.

6. The dotted Parallel of Declination $23^{\circ} \frac{1}{2}$ North of the Equinoctial is the *Tropic of Cancer*, as is that $23^{\circ} \frac{1}{2}$ South of the Equinoctial the *Tropic of Capricorn*.

7. The dotted Parallel $66^{\circ} \frac{1}{2}$ North of the Equinoctial is called the *Arctic* or *Northern Polar Circle*; that in the South, at the same Distance from the Equinoctial, is the *Antarctic* or *Southern Polar Circle*.

8. The dotted Line passing thro' the Center in an oblique Position making an Angle of $23^{\circ} \frac{1}{2}$ with the Equinoctial is the *Ecliptic*; it is divided by little Lines (") into every 5 Degrees, and subdivided into Degrees by Dots (.)

On each Side of it, at 8 Degrees Distance, is drawn a parallel Line, and the Space contained between these Lines is called the *Zodiac*, in which the *Planets* are always found.

9. The strong elliptic Lines, are *Hour Circles*; the less strong *Half Hours*; and those dotted are *Quarters of Hours*.

10. The large Plate contains the following Particulars, besides the *Meridians* and *Prime Vertical*, the *Horizon* S. N. which is divided into Degrees counted from the East or West Point towards the North and South, for finding the Amplitude of the Sun or Star; and under these Degrees, into Points and Quarter Points of the Compass, counted from the North or South towards the East or West, to shew readily on what Point of the Compass the Sun or Star rises or sets, &c. And to know the corresponding Point of the Compass, in the Right-Hand upper Corner

Corner is engraved a Compass, for such Youths as have not learnt the Sea Compass.

11. In the same Corner is * R. A. — $\odot$ R. A. or
 $* R. A. + 24^h - \odot R. A.$
 $= * \text{Southing}.$

which is to be thus read, The Stars Right Ascension *Minus* (or less) the Sun's Right Ascension: Or the Stars Right Ascension *Plus* (or more) 24 Hours *Minus* the Sun's Right Ascension is equal to the Stars Southing. The Use of this will be explained hereafter.

12. Under the Horizon on the Left Hand is a Calendar for our Summer, and on the Right another for our Winter half Year, containing the Days of the Month, Sun's Right Ascension, Place and Declination corresponding thereto, which we shall have Occasion to explain more particularly in the Problems.

13. In the Middle between the Calendars is a Table shewing the Right Ascension and Declination of the Principal Stars; which being calculated for some Years hence, will be sufficiently accurate for many Years to come.

14. PROBLEM I. The Day of the Month being given to find the Sun's Place in the Ecliptic. This is done by Inspection of the Calendar only.

EXAMPLE. Thus it will be seen that the 20th of March the Sun enters *Aries*, the 20th of April *Taurus*, May the 21st *Gemini*, the 21st of June *Cancer*, the 23d of July *Leo*, the 23d of August *Virgo*, September 22d *Libra*, October 23d *Scorpio*, November 22d *Sagittarius*, December 21st *Capricornus*, January 20th *Aquarius*, February 18th *Pisces*.

N. B. The Line for the Sun's Place is marked $\odot$ P and is divided into every 5 Degrees by Dashes (—) and subdivided into Degrees by Dots (·).

15. PROBLEM II. By the Sun's Place in the Ecliptic to find the Day of the Month.

This

This being only the Reverse of the former, needs no particular Explanation.

16. PROBLEM III. By the Day of the Month to find the Sun's Declination. This may also be found by barely inspecting the Calendar. Thus for Example January 20th against that Day of the Month in the Column D. you will find the Sun's Declination 20 Degrees South.

But if the young Student is inclined to solve this Problem on the Analemma, it may be done thus. Bring the Equinoctial to the Horizon and the Southern Part of the Ecliptic above the Horizon, then looking for the Sun's Place corresponding to the Day of the Month (which in the present Example is 0° Aquarius) observe what Parallel of Declination crosses that Place, and we shall have the Declination, in the present Example 20° as afore found.

17. PROBLEM IV. By the Sun's Declination to find the Day of the Month.

This is also readily done by Inspection of the Calendar.

Let the Example be the Reverse of the last, viz. the Sun's Declination being 20 Degrees South, what is the Day of the Month? Answer, it appears by the Calendar that it may be either the 20th Day of January or the 21st Day of November.

If it be required to solve this Example on the Analemma, bring the Southern Part of the Ecliptic above the Horizon, and the Equinoctial in the Horizon, then will the Parallel of Declination, in our Example the 20th Degree, cross the Ecliptic in 0° of *Sagittarius*, and 0° of *Aquarius*, the two Places of the Ecliptic in which the Sun has that Declination. Hence by Problem II. the Days are as above.

18. PROBLEM V. To rectify the Analemma for any particular Place.

This is only to bring the Pole to the Latitude of the

the Place, the North Pole to the North Meridian, if the Place is in North Latitude; but the South Pole to the South Meridian for South Latitude.

19. PROBLEM VI. To find the Sun's Amplitude, or on what Point of the Compass the Sun rises and sets at any given Place on any given Day.

Rectify the Analemma by the last Problem; and by the Day of the Month find the Sun's Declination, by Inspection of the Calendar as shewn in Problem IIIId. Then will the Parallel of that Declination cut the Sun's Amplitude on the Horizon.

EXAMPLE. On what Point of the Compass does the Sun rise and set at London (Latitude $51^{\circ} \frac{1}{2}$ North) the 20th of June? Working as above directed it will be found that the Sun rises E. 40° N. and sets W. 40° N. or rises nearly N. $4 \frac{1}{4}$ Points E. and sets N. $4 \frac{1}{4}$ W. which answer to N. E. $\frac{1}{4}$ E. and N. W. $\frac{1}{4}$ W.

20. PROBLEM VII. To find the Time of Sun Rising and Setting, Length of the Day and Night at any given Place, whose Lat. does not exceed $66^{\circ} \frac{1}{2}$.

Rectify the Analemma, and find the Sun's Declination for the given Day, then observe what Hour Circle cuts the Horizon, and it will shew how much the Sun rises before or sets after Noon.

N. B. In South Latitude the Hour Circles on the Analemma are each numbered from Midnight; and so shew the Time of Sun rising, as the Numeral Hours in North Latitude do the Time of Sun setting.

EXAMPLE. On June 20th at London Latitude $51^{\circ} \frac{1}{2}$ the Sun's Declination being $23^{\circ} \frac{1}{2}$ North, it will be found that the Sun rises about $8^h \frac{1}{4}$ before Noon or 3 Quarters after 3 in the Morning; and sets a Quarter after 8.

Hence the Length of the Day being equal to double the Sun's setting is equal to $16^h \frac{1}{2}$, and as the Sun's Declination in the Example is the greatest, it shews that $16^h \frac{1}{2}$ is the longest Day at that Place.

21. PROBLEM VIII. To find the length of the longest Day at any Place in the Polar Circles.

R. 3.

To

To illustrate this let the Place be Hacluit's Head-land in Greenland, Lat. 80° North.

Rectify the Analemma, then you will readily see that when the Sun comes to 10° Declination (equal to the Complement of Latitude of the Place) the Sun would 12 Hours after Noon come to the Horizon in the North but not set; this corresponds to the 16th of April; from which Time the Sun being going to the Northward continues above the Horizon till it returns to 10° North Declination again, which in the Calendar answers to the 27th of August. Hence it appears that it is *all Day* at that Place, from the 16th of April to the 27th of August.

In the same Manner it will be found that at the Poles or in 90° of Latitude either North or South, there is but one Day and one Night in a whole Year.

22. PROBLEM IX. To find the Sun's Altitude at a given Place, at any given Day and Hour.

This admits of 3 Cases:—

First. When the Meridian Altitude is required, rectify the Analemma, then will the Parallel of Declination cut the Meridian in the Altitude required.

EXAMPLE. The Sun's Meridian Altitude at Noon at London the 1st of May, will be found to be $53^{\circ} \frac{1}{4}$.

Case 2. When the Sun's Altitude is required at the Time it is East or West.

The Analemma being rectified, observe what Degree of the Prime Vertical is cut by the Parallel of the Sun's Declination, and that will be the required Altitude.

EXAMPLE. On the above Day it will be found to be $19^{\circ} \frac{1}{4}$.

Case 3. When the Altitude is required at any other Time of the Day.

Rectify the Instrument and observe where the Parallel of Declination intersects the given Hour Circle; then placing one Leg of a Pair of Compasses on that Point, extend the other Leg to take the nearest Distance to the Horizon; then will

will that Distance measured on the Prime Vertical give the Altitude required.

EXAMPLE. At London Latitude $51^{\circ} \frac{1}{2}$ N. the 21st of June at 3 in the Afternoon, the Sun's Altitude will be found to be $45^{\circ} \frac{1}{2}$.

23. PROBLEM X. Given the Latitude of the Place, Day of the Month and Altitude of the Sun (taken by a Quadrant or other Instrument) to find the Time of the Day.

Rectify the Analemma, then lay a String across both Meridians so that it may cut the Sun's Altitude on both Meridians; then, where the String crosses the Parallel of Declination, that is the Place of the Sun, and consequently the Hour Circle passing through that Place, will shew the Time required.

Let the Example be the reverse of the last Problem.

24. PROBLEM XI. To find the Sun's Depression at Midnight.

Rectify the Analemma, and as many Degrees as the Sun is below the Horizon, so many Degrees will the Parallel of equal Declination, but with contrary Name, be above the Horizon at the other Meridian.

EXAMPLE. In Latitude $51^{\circ} \frac{1}{2}$ North, on the 15th of April, it will be found that the Sun is $28^{\circ} \frac{1}{2}$ below the Horizon (in the North).

25. PROBLEM XII. To find the Beginning, and Duration of Twilight.

Twilight begins and ends when the Sun is 18° below the Horizon.

Rectify the Analemma, then laying a String across 18° of Altitude on both Meridians, observe where it intersects a Parallel of Declination equal to that of the Sun, but with opposite Name; and the Hour Circle passing through that Place will shew the Time of the Beginning of Twilight, counted from Midnight.

Thus for Example, it will be found that Twilight begins or Day breaks the 1st of October at London at

at $\frac{1}{4}$ after 4 in the Morning, and the Sun rises that Day at $6^h \frac{1}{4}$, so that the Duration of Twilight in the Morning is 2 Hours, and it being the same in the Evening after Sun set, will be in all that Day 4 Hours, which added to the Length of Day $11^h \frac{1}{2}$ gives the Time from Day-break to dark Night $15^h \frac{1}{2}$.

Note, From the End of May to the Middle of July, there is no dark Night, in the Latitude of London.

26. PROBLEM XIII. To find what Day of the Year the Sun will be vertical to a given Place in the Torrid Zone.

As the Latitude is counted from the Equator on the Terrestrial Globe the same Manner as the Declination is counted from the Equinoctial; we have nothing to do but to find on what Days the Sun's Declination is equal to the Latitude of the Place, and of the same Name.

EXAMPLE. Thus at Jamaica (Lat. $17^\circ \frac{1}{4}$ North) it will be found the Sun is vertical or passes directly over Head at that Place the 10th of May and 2d of August.

Hence it appears that those Places which lie between the Tropics may be said to have two Summers in a Year.

27. PROBLEM XIV. Given the Latitude of the Place Day of the Month, and Altitude of the Sun taken (by a Quadrant) in the Fore or Afternoon, to find the Sun's Azimuth.

Rectify the Analemma and find the Sun's Declination; then laying the fiducial Edge of a Ruler to cut the Sun's Altitude on both Meridians, observe where the Edge of the Ruler cuts the Parallel of Declination, for that is the Sun's Place; against which on the Edge of the Ruler make a Mark with a Pen or Pencil, also where the Ruler crosses the Prime-Vertical; then taking off the Ruler, bring the Pole to the Zenith, and the Hour Circles become Azimuth Circles. Then, placing the Ruler

as before, which may be easily done by the Sun's Altitude and the Marks above directed to be made, observe which Hour (now Azimuth) Circle passes by the Sun's Place marked on the Ruler, then that Hour (or Azimuth) Circle will on the Horizon shew the required Azimuth.

EXAMPLE. At London in Lat. $51^{\circ} \frac{1}{2}$ N. the 21st of August, when the Sun's Altitude is $41^{\circ} \frac{1}{2}$ in the Forenoon, his Azimuth is S. 57° E. which is nearly 5 Points from the South towards the E. or S. E. by E. and in the Afternoon when the Sun has the same Altitude it is S. W. by W.

Note, This may also be solved by Means of the Horn hinted at in the Scholium to the next Problem.

28. PROBLEM XV. To find the Sun's Azimuth at any given Day and Hour at any Place.

This admits of 3 Cases.

Case 1st. At Noon or Midnight, the Sun is on the Meridian, and so must be either North or South.

Case 2d. To find the Sun's Azimuth at any other Time of the Day.

Here, as the Azimuth Circles could only be laid down on the Moveable Circle for a particular Latitude, that Defect may be thus supplied.

Having rectified the Analemma and found the Sun's Declination: The Place where the Parallel of Declination cuts the given Hour Circle, is the Place of the Sun for that Time. With a Pair of Compasses take the nearest Distance from that Place to the Horizon, which measured on the Prime-Vertical, will shew the Sun's Altitude at that Time. This done, lay the fiducial Edge of a Ruler to cut each Meridian in the Sun's Altitude, then observe where the Ruler intersects the Place of the Sun above found, and the Prime-Vertical; against each of these Places make a Mark, with a Pen or Pencil on the Edge of the Ruler.

Now turn the moveable Circle 'till one of the Poles comes in the Zenith, then may the Hour Circles

Circles be looked on as Azimuth Circles. Then the Ruler by the Marks made on its Edge, may be easily placed in its former Position; which being done, observe what Hour Circle (now Azimuth Circle) intersects the Ruler at the Mark made for the Sun's Place, and carrying your Eye along that Circle 'till you come to the Horizon, you'll see the Azimuth required.

EXAMPLE. At London, the 21st of June at 3 o'Clock in the Afternoon, it will be found, that the Sun is about 6 Points from the South towards the West, that is, about W. S. W.

29. SCHOLIUM. If the Azimuth Circles be drawn on a Quarter of a Circle, made of clear Horn, then as the Hour Circles, &c. can be seen thro', the Azimuth may be found by Inspection. Such a Horn may be made for Six-pence; and if requested, may be had with the Instrument at that Price.

PROBLEM XVI. Given the Latitude of the Place and Day of the Month to find on what Time of the Day the Sun will be on a given Azimuth.

Rectify the Analemma, and find the Sun's Declination, then lay the Horn so that the Zenith of the Horn may be in the Zenith of the Instrument, that the Line drawn on it from the Zenith may lie on the Prime Vertical, and that the Line on it perpendicular thereto, may lie in the Horizon, &c. then we have only to observe where the given Azimuth crosses the Parallel of the Sun's Declination, and that will be the Place where the Sun is at that Time; and consequently, the Hour Circle passing by that Place, will be that required.

The Example may be the Reverse of that in Problem XV.

Of the STARS.

30. PROBLEM XVII. To find the Time of a Star's coming on the Meridian (or when its Altitude is

is the greatest possible for that Day) vulgarly called the Southing.

We have already given the Rule in Art. 11.

EXAMPLE. What Time is *Arcturus* South, the 17th of May.

In the Table of Stars on the Instrument,
the Stars Right Ascension is - - $14^h 5'$

The Sun's R. A. by Inspection of the
Column R. A. of the Calendar is - $3 \quad 38$

Remains $10 \quad 27$

That is, *Arcturus* is South that Night at 27 Minutes after 10.

31. SCHOLIUM. The Manner of Working for the Stars, Moon, Planets, &c. is so near that of the Sun, that it seems only necessary to hint, that the Declination of the Stars being taken out of the Table of Stars, and of the Moon or Planets from an Ephemeris or Annual Almanack, work for the Stars, &c. in the same Manner as has been shewn in the Problems for the Sun; only it must be noted, that the Time found by such Operation must not be considered as so many Hours before or after Noon; but so many Hours before or after the Southing of the Star, Moon, or Planet.

Thus for Example, if it be required to find the Time of *Arcturus* Rising and Setting the 10th of May at London.

By rectifying the Analemma, the Declination of the Star being $20^{\circ} 24'$ N. we shall see by inspection that its semidiurnal Arc, or Time of the Stars setting after its Southing is $7^h 50'$.

The

The Time of Southing being $10^h 27^m$
 Subtract and add semidiurnal Arc } $7 50$

Gives Time of Rising $2 37$ after Noon.

And the Star sets after Noon } $18 17$
 of 17th Day - - - - - }
 Subtract 12

Gives Star's Setting the next } $6 17$
 Morning at - - - - - }

Many other Problems might have been given, but if the Reader rightly understands what is already delivered, he will not find it difficult to solve more, without any further Assistance.

F I N I S.

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